WORLD PETROLEUM

NEW YORK OCTOBER 1938 LONDON

DRIVE AGAINST AMERICAN INVESTMENTS

EFFECT OF WAR ON OIL TRADE

COST OF GEOPHYSICS

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Placing Tubing in a California Derrick.

EDITORIAL

WHY NOT TELL THE FACTS?

FOR fifty years and more the oil industry of the United States has been the object of repeated attack and constant misrepresentation. These assaults have come from many sources—from writers seeking by sensational charges to create a market for their wares, from political demagogues, from public officials following a well-trodden path to personal preferment.

The growth of the industry itself, due to the swift expansion in the demand for its products, has made it a shining target for political shafts. In an era when warped economic ideas prevail in high places, when it is the fashion in such circles to deride success and to discourage enterprise, when federal officials can indict a prominent corporation on the ground that its unparalleled success "creates a strong inference that there existed abnormal or artificial barriers to competition," efficiency alone becomes presumptively a crime. At least it is an open invitation to attack.

The oil industry itself has done little in the past to offset the long continued campaign of misrepresentation waged against it. For years it has been too busy with its daily job of increasing production to satisfy swiftly growing requirements, with the adaptation of its output to meet changes in demand, and with the improvement of its processes to provide constantly improving products at steadily declining prices. This is not to say that its record of performance has been flawless. By and large, however, it remains true that in scarcely any other field of effort has so much been accomplished, in so short a span of time, for the comfort and convenience of the average man and woman and for the greater efficiency of industry as a whole, as through the everyday business of producing, processing, and marketing petroleum.

The oil industry has a story to tell, a simple story of unremitting effort by an army of determined workers to satisfy a demand that has multiplied fivetold in twenty years, a story of disappointments and losses uncomplainingly borne and of gains promptly shared with consumers, of millions spent in research to improve and cheapen established products and to develop new ones, of contributions to the cost of government such as no other single industry has been called upon to make.

All this is important at a time when a persistent campaign is being waged to bring the oil industry under the control and direction of the federal government and when measures of restriction, regulation, inspection, and taxation are being put forward in half the state legislatures of the land.

Once the heavy hand of government dictation is laid upon the oil industry the incentive to improvement will be removed, enterprise will be penalized and the industry will become static as have those others that have been brought under the political yoke. It is worth a strenuous effort to avoid such an outcome.

Recently the American Petroleum Institute announced the establishment of a committee to deal with the dissemination of accurate information pertaining to fundamental facts of the oil business. The intention is to enlarge this committee until it embraces all branches of the industry and has representatives in all parts of the country.

This is a sound step and one that should have been taken long ago. If the members of the committee appreciate the importance, in addition to such collective action as may be decided upon, of making known, each in his own circle and through means at his command, the simple facts about the industry, the progress it is constantly making, its exceptional labor record, and the service it is continuously rendering to the public, much good will result. The oil industry does not need a huge campaign of propaganda but it does need quiet, continuous, effective work to make its true story better known.

DRIVE AGAINST AMERICAN INVESTMENTS

MEXICO, D. F.

AN ORGANIZED drive against capitalism and in particular against what was designated as American financial imperialism was set on foot at the labor union congress held in Mexico City September 5-8. Among the purposes held in view by the promoters of the congress may be listed the following: to build up the power of Vicente Lombardo Toledano, sometimes referred to as the "labor king" of Mexico; to support President Cardenas in his stand against the demand of the United States of payment for properties confiscated from its citizens; to add to the prestige and influence of Mexico throughout Latin America, and to forward a movement for radical labor union domination of all countries south of the Rio Grande.

That these objectives were not more clearly understood by the outside world was due to circumstances surrounding the congress itself. First of all, there were three meetings which took place in the same week, one directly following another. These were the conference of the I.R.I., the Latin American labor congress and the Congress against War and Fascism. All three gatherings were composed of practically the same elements, but the most resounding speeches and those most fully reported were directed against fascism, a designation which the majority of the speakers seemed to regard as interchangeable with "capitalism." The press releases given out were carefully modified versions of the speeches and discussions which actually took place. Those which were prepared in English were less radical than the ones given out in Spanish. In the publicity department there was obvious care not to allow the impression to be created in the outside world that the congresses were communistic in make-up.

In the meetings themselves no such restraint was imposed. The Fine Arts Theater in which they were held had all the atmosphere of a party gathering in Moscow. It was decorated lavishly, particularly during the Congress Against War and Fascism, with red banners featuring the Soviet star, the hammer and sickle, portraits of Lenin and Marx. Most of the speakers greeted the audience with the clenched fist salute of communism. In the discussions that went on outside the regular meetings the delegates who had visited Russia were those who spoke with most authority and who were listened to with the greatest deference.

The labor union congress was made up, aside from the Mexican members, of some 40 delegates from 13 countries including Argentina, Bolivia, Chile, Colombia, Cuba, Ecuador, Paraguay, Peru, Nicaragua, Costa Rica, Puerto Rico, Uruguay and Venezuela. The largest delegation was that of Cuba with 14 members. The other countries were represented by one to four delegates each.

Besides these regular delegates were a certain number of "brotherly delegates," including visitors from the United States and Europe. From this former country two who were so described were John L. Lewis, head of the C.I.O., and A. F. Whitney. Another whose presence was pointed out by the managers of the meetings as especially significant was Edwin S. Smith of the National Labor Relations Board of the United States. Mr. Smith's denial that he was present in an official capacity was widely printed in American newspapers but no such impression was gained by the Mexican people. Quite the contrary.

None of the visitors from the United States apparently had any official part in the labor congress, but this did not prevent Lewis making a speech in which he lauded the head of the Mexican government and Mexico's labor policy. In this speech he coupled the names of President Cardenas and President Roosevelt as "two great statesmen with friendship in their hearts for labor." Mr. Smith in a speech before the I. R. I. bitterly assailed capitalism and praised the Mexican labor law saying, "No country with a capitalistic structure, with the exception of Mexico, has had the courage to give the worker the guarantees that protect the right of organization in such a perfectly clear and forceful manner as those contained in the (Mexican) labor code."

The active participation of Mr. Smith and his presence on the platform at the opening session of this so-called Congress against War and Fascism was pointed out to the Mexican people as convincing evidence that the government at Washington was in full sympathy and accord with everything that Mexico has done from land seizures to oil confiscation and that the attitude of the Department of State was not shared by the rest of the Roosevelt administration. The great influence of John L. Lewis with the administration and his close relations with its leaders was cited as further proof of the close sympathy of Washington with everything that President Cardenas has done.

There can be no question in the minds of those who attended these meetings in Mexico City, saw the way they were handled and read the reports issued by their publicity representatives that they strengthened the belief which previously had been carefully nurtured among the people of Mexico that the dominant powers in the government of the United States were in full accord with the policy of confiscation. If the whole demonstration had been arranged to destroy any possible effect of the repeated protests of the American State Department it could hardly have been more effective.

On the final day of the labor meeting a permanent organization was established for the Latin-American Labor Alliance. As its president Vicente Lombardo Toledano was elected. The secretary-general is Fidel Velasquez, also of Mexico, and the headquarters of the organization is to be established in Mexico City. Francisco Perez Leiros of Argentina was elected vice-president and Clodomiro Clavijo of Colombia second vice-president. Three zones of regional activity were designated. Regional secretaries for the south and central zones were appointed and one for the north zone is still to be selected. For the financial support of the organization dues were fixed according to the membership of allied unions with an extra fee equal to one month's regular dues to cover expenses for the installation of the central committee.

The inspiration and the direction of this newly launched movement is to be Mexican, that is to say, communistic. Its purpose is to shape the union labor movement in all Latin America, if possible, along the lines followed by the C.T.M., the Mexican union led by Lombardo Toledano. It will be violently against the financial imperialism of the United States and will endeavor to influence other Latin American countries to adopt the policy of confiscation inaugurated by Mexico.

As a result of these recent developments it is clear that the issue between the governments at Washington and Mexico City no longer is one merely of payment for lands and properties. A subtle systematic war designed to spread hatred of the United States and to destroy the investments of its citizens in all Latin America has been started by men who are schooled in all the arts of political penetration known to Moscow. This is the big, the vital issue to be faced and dealt with.

WAR'S EFFECT on Petroleum Trade

German Deficit of Four and a Half Million Tons—Eastern Mediterranean Cut Off—Far East Shipments Reduced: U. S. Would Have to Increase Production to 4,000,000 Bbl. per Day—Demand for South American Exports Up 14 Percent.

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Germany's vast program of motorization of her armed forces has left her more and more dependent upon motor fuel.

WAR clouds hovering over Europe suddenly grew blacker during September. With armies mobilized, battleships stripped for action and planes concentrated at their flying bases it seemed many times that the start of the conflict might be only a few hours away. Each postponement was followed by a fresh crisis and even the recent Munich settlement may prove temporary.

All this has given a practical importance to the question as to what would be the effect upon the petroleum industry of a general war and of the influence that petroleum itself might have upon the result of the struggle.

Comparison with the situation twenty-five years ago throws little light upon the subject. When the great war of 1914 started the motorization of industry—and of war—had only begun. Motor transport was undeveloped—witness the historic spectacle of the taxicabs of Paris rushing reenforcements to save Joffre in the first battle of the Marne. At that time the airplane was a weapon of unknown possibilities. The tank was a development of the war itself. The world's peace time consumption of petroleum was at the rate of 55,000,000 tons a year; today it is 275,000,000 tons. In that earlier conflict oil played a part of steadily increasing importance. In the end it was credited with having wrought the allied victory. But its rise to this leading role was a gradual one, brought about by experience gained in the fighting itself.

In 1938 the situation is far different. At the first note of war any one of the larger European countries could launch an airfleet greater in number than all the planes that fought on all fronts in the years from 1914 to 1918. Every army that set out would move by truck with fully motorized equipment. The consumption of petroleum products would jump almost at once to its wartime maximum.

What would that increase be? A great deal of careful study and expert figuring has gone into the attempt to answer that question. In Germany, where subjects such as these are most certain to receive thorough investigation, statisticians have estimated wartime requirements of petroleum products at 12,650,000 tons per year. Of this approximately one-half would consist of Diesel oil, including 1,500,000 tons for aviation purposes. As is well known Germany is far ahead of other nations in the utilization of Diesels, the great majority of commercial vehicles and a large proportion of her planes being fitted with Diesel engines.

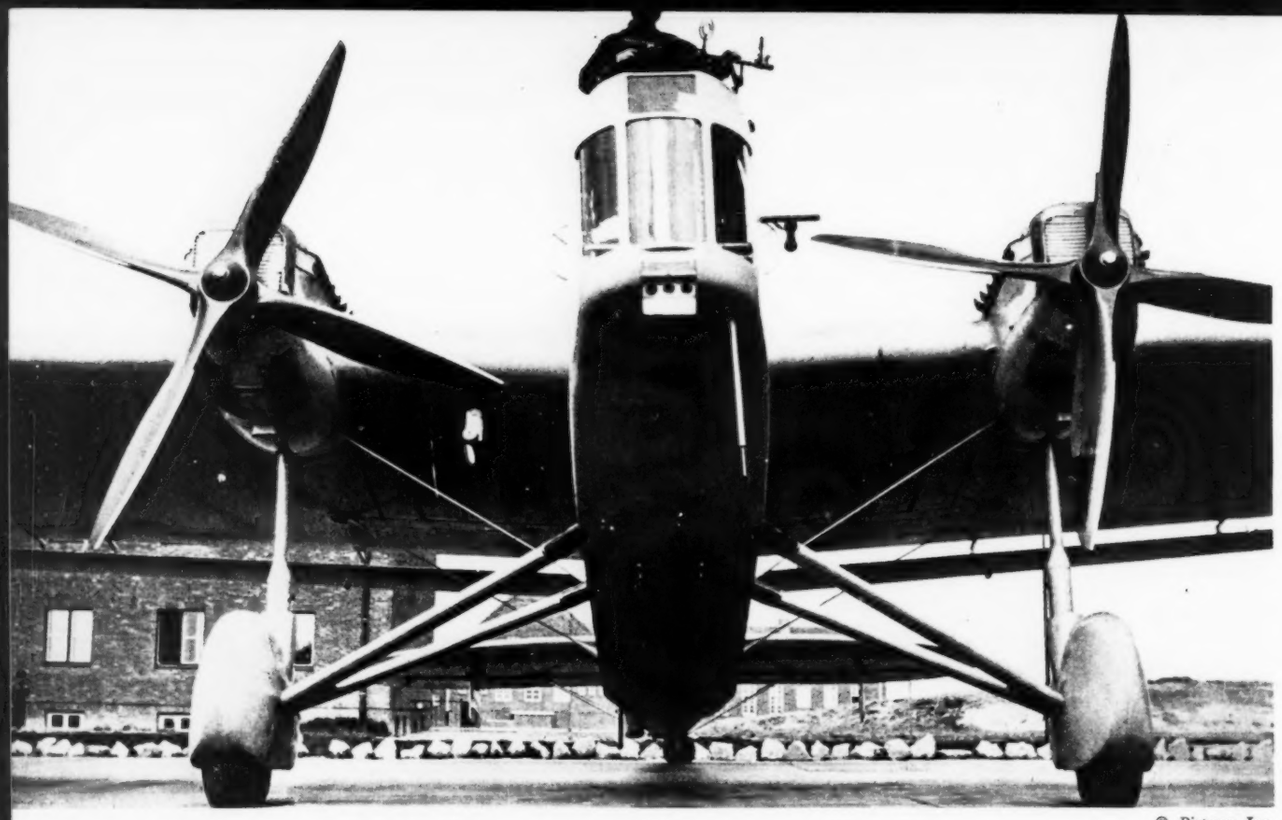
As compared with this estimated wartime consumption of 12,650,000 tons Germany has been using during the past two years between 5,000,000 and 6,000,000 tons. Little more than a doubling of peace time consumption is contemplated, therefore, in order to carry on a war under modern conditions. This seems a low estimate even though it contemplates rigid curtailment of motor fuel for civilian uses.

Production available for German use would include 475,000 tons from Germany, 35,000 tons from Ostmark (Austria) and 18,000 tons from Czechoslovakia. To this might be added Roumania's 7,150,000 tons and Poland's 501,000 tons shortly after the outbreak of hostilities making a total of 8,179,000 tons.

Italian demand in peace time amounts to 1,830,000 metric tons. Assuming that not less than twice this amount would be required in the event of war, Italy falls far short of this figure, having at her command only the indigenous production of 15,000 tons and Albanian production of 90,000 tons.

Together, Germany and Italy, requiring 16,310,000 tons in wartime, would have available at best only 8,284,000 tons, leaving a substantial balance of 8,026,000 tons which would have to be made up partly from synthetic fuels and partly from imports.

Several months ago General Serrigny, head of the association representing the petroleum industry of France and a former member of the Supreme Defense Council of the country, delivered an address in which he declared that in the event of war Europe's imports of petroleum and its products would have to be at the annual rate of 60,000,000 to 70,000,000 tons. These figures, it will be noted, referred to imports in addition to native production and the speaker stated that they represented a minimum of actual needs. As he was refer-



Plane of the Hindenburg air squadron with machine gunner's cockpit in front —even the Reich cannot synthesize Diesel oil from coal and therefore would face a shortage of this product unless it can maintain a free flow of petroleum from abroad.

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ring to nations likely to be involved in a general European war his estimate apparently was that war would bring about a demand for two and a half times the ordinary commercial imports.

For the United Kingdom various estimates by independent authorities place the additional quantity of petroleum products required to satisfy war demand at 25,000,000 to 35,000,000 tons or a total of from two and a half to three times ordinary commercial needs. In this case a substantial part of the estimated increase is attributed to fuel oil needed by naval vessels convoying transports or food ships. No doubt the British government has made a careful calculation of its probable requirements under war conditions but this, of course, has not been made public.

Taking the figure of 70,000,000 tons mentioned by General Serrigny as a conservative estimate of the yearly imports required by the principal European countries under war conditions a second pertinent question is suggested. How and where is this additional amount of oil to be obtained?

To add 38,000,000 tons of oil to the world's supply and to transoprt and distribute this large quantity would not be an impossible task under normal conditions. But war itself is an abnormal condition and it is to be expected that some established trade routes would be blocked and that some countries might be cut off from their customary sources of supply.

Speaking broadly there are four main areas which supply oil required to keep the wheels of industry turning in countries which are without indigenous production or in which supplies are insufficient for domestic needs. Of these four exporting districts two are in the Western Hemisphere and two in the Eastern.

In North America the United States and Mexico are the two countries that have figured in an important way as exporters. Venezuela, Colombia, Peru, and Ecuador are the only petroleum exporters from South America. A third important group consists of countries clustered around the eastern end of the Mediterranean, including Roumania, the Soviet Union and Iraq. The last named country is included in this group because the only outlet for its oil is by pipelines terminating on the eastern shore of the Mediterranean. The fourth group comprises Iran and Bahrein on the Persian Gulf and Netherlands India. To reach Europe oil from all of these countries in the last two groups must travel through the Suez Canal and the Mediterranean or make the long sea voyage around Cape of Good Hope.

In round figures the exports from these four producing sections, in tons, have averaged about as follows during the past three years:

North America	21,000,000
South America	28,000,000
Mediterranean group	12,000,000
Eastern group	14,000,000
Total	75,000,000

Broadly speaking the above represents the world's export of oil. The shipments go to all quarters of the globe but the largest portion, some 33,000,000 tons, goes to supply the needs of Europe. War, as already noted, would double or possibly treble Europe's import requirements. It would not lessen the demands of non-belligerent nations. The problem therefore, would be to obtain from one or all of the four principal producing areas further 40,000,000 to 50,000,000 tons in addition to any part of the present supply that might be shut off from its customary markets by war conditions.

In the event of a general war participated in by Great Britain, France, Germany and Italy, and possibly involving also the Soviet Union, Japan and several of the smaller European nations, some part of the present export supply would almost certainly be bottled up or diverted to channels other than those which it had followed in time of peace. In the world war in 1914-18, it will be remembered, Roumania's oil was of little use to the nations with which Roumania was allied, but it was of great importance to the Central powers who held possession of the Roumanian oilfields during a considerable part of the conflict. Control of Roumanian oil is one of the undisguised objectives of Hitler's march to the east and one of Germany's first war moves undoubtedly would be to seize such control.

In any struggle at arms in which the Soviet Union took part exports from that country would cease. In fact Russia would become an importer of motor fuel for her air service.

If the Rome-Berlin axis held good in a European war, trade routes across the Mediterranean to western Europe would be blocked. At least they would become too hazardous for the movement of oil from Iraq which now is a chief source of supply for France. Some part of it might be able to move from the pipeline terminals through

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Czechoslovakian tanks engage in maneuvers near Milovice, Bohemia (above), while (right) Germany's shipyards resound with the noise of rivetting machines building up an oil tanker fleet.

the Red Sea and around the southern tip of Africa to reach the ports of western Europe, but the volume would be greatly reduced as tankers could be used more effectively on the Atlantic. For practical purposes it would be safer, in calculating available supplies, to eliminate oil from the eastern end of the Mediterranean.

From the Persian Gulf oil could move across the Indian Ocean, around Africa and up the Atlantic to British and French ports but the voyage is a long one of over 11,000 miles. It would require many tankers to move the oil over this route and many convoys to insure the safety of the cargoes. It is doubtful whether it would be practicable to move in this way the whole of the 9,000,000 tons produced in Iran and Bahrein. At a most conservative estimate, shipments would be reduced by at least one-third, making the total supply for Europe from the Near East 6,000,000 tons. The 5,000,000 tons available from Netherlands India would either go to supply operations in the Far East or would be rendered for the most part unavailable in Europe because of the great distance over which it would have to be transported. The exception would be limited quantities of Borneo crude for manufacture of toluol for explosives.

To meet the heaviest part of the wartime demands of France and England it would be necessary to have recourse to the Western Hemisphere. Here the distances to be covered are shorter, the difficulties of protecting shipments are less and, most important of all, the possibilities of quickly expanding output are far more favorable than elsewhere. With the rapid development now going on in the two most important producing countries of South America, Venezuela, particularly eastern Venezuela, is in a position to increase its output immediately and Colombia soon will be. Mexico is an uncertain factor since the confiscation of oil company properties last March, but there is no doubt that under favorable operating conditions its production could be greatly expanded.

In the United States is to be found the combination of all the conditions needed for an immediate large expansion of output,

for the processing of oil into products in whatever proportion might be required and for transportation under most favorable conditions. To raise daily output from its present 3,300,000 bbl. to the required 4,000,000 bbl. would be a simple matter of increasing allowables in the states where proration prevails and to make increased production economically worth while elsewhere.

Deducting from General Serrigny's estimated demand for all Europe in wartime, the requirements for the Rome-Berlin axis, which might be impossible to obtain from the Western Hemisphere, Allied Europe would require some 22,000,000 tons additional. It is necessary to add a further demand for 12,000,000 tons now supplied from the Mediterranean group, likely to be rendered unavailable during an international crisis, and 3,000,000 tons by which Iran, Bahrein and Netherlands India shipments would have to be reduced due to the longer route around the Cape of Good Hope. Therefore, a minimum of 37,000,000 tons more per year would apparently have to be supplied from the Western Hemisphere.

Production in the United States amounts to about 173,000,000 tons while that of Mexico and the exporting countries of South America totals some 92,200,000 tons. An increased demand from Europe (exclusive of the Rome-Berlin allies) of 37,000,000 tons would amount to a 14 percent increase in the production of the exporting countries of North and South America. In the United States this would necessitate a daily output of approximately 4,000,000 bbl. against an output of 3,329,000 bbl. per day in July of this year. In Venezuela 585,000 bbl. per day would be required, while current production is but 501,000 bbl. An increase of 8,000 bbl. per day would be required in Colombia to bring production up to the 64,000 bbl. while in Peru production would have to rise to 55,000 bbl. per day from a current 45,000 bbl.

A French oil tanker armed for self-defence during the last war.

Courtesy Olivier Lesourd

This estimate does not take into account possible losses of cargoes due to submarine attacks. During the last world struggle these lossses amounted to ten percent of the total. There is no reason to assume that they would be less in a new war. To provide for this contingency, calculated production would have to be increased by another ten percent.

While western Europe, and France in particular, has greatly expanded its refining facilities since the last great war it would be impractical, for various reasons, to meet added requirements by the importation of crude. For the conservation of their own man power, for economy of space in transportation and for convenience in distribution it would be to the advantage of the nations engaged in fighting to receive their supplies as largely as possible in the form of finished products. General Serrigny, in the report previously mentioned, recognized this fact by estimating that two-thirds to three-quarters of total war supplies would need to be in the form of finished products. The United States has unoccupied refinery capacity sufficient for a greatly increased production of motor fuel including high grade aviation fuel. It happens too that the United States today has the largest stocks of gas and fuel oils in its history and could meet promptly the heavy demand for these grades of fuel that would make itself felt immediately on the outbreak of hostilities.

In the event of a general war it seems inevitable that Great Britain, France and such other countries as might be allied with them would turn to the United States and South America for the additional supplies of oil needed in such a struggle. While Venezuela and Colombia do not possess within there own borders extensive facilities for converting crude into products two of the world's greatest refineries are located close at hand in the Netherlands West Indies and would serve to process large quantities of oil. Their capacity could be enlarged quickly.

It must be borne in mind also that Great Britain has two sources of supply on the western side of the Atlantic in Trinidad and Canada. Both of these are increasing their production rapidly. While the Canadian fields are far removed and Canada is still an importer of oil its refining and shipping facilities in the east would be invaluable to the mother country in time of war.

A study of available supplies and of the possibilities of quickly increasing production indicates that in a war involving the principal countries of Europe it would be necessary for Britain and France to look to the western side of the Atlantic for the oil supplies needed to carry on such a war and that the western hemisphere would be capable of satisfying their needs. There remains the question of available transport but with the great increase in tanker capacity that has taken place within the past two years and with the possibilities of conversion such as was resorted to in 1914-18 this phase of the problem presents no insuperable difficulties.

Of the 70,000,000 tons estimated wartime consumption by Europe, probably 16,000,000 would be by Rome-Berlin allies, leaving 54,000,000 to be carried from the Americas to the other allied and neutral countries of Europe. In a war emergency Great Britain and her allies would be driven to dependence on neutral tonnage of which presumably that of Norway would be the most readily available. This would be a reversal of the situation during the last war when the rest of Europe depended upon Britain's huge tanker fleet to maintain oil supplies.

Great Britain has a commercial tanker fleet of about 4,000,000 tons capacity, in addition to which the Admiralty owns 378,000 tons of naval oilers. The Netherlands' privately-owned tankships total some 840,000 tons deadweight while the French merchant marine includes 360,000 tons and her navy operates tankers of 108,000 tons capacity. These combined fleets number 649 units capable of carrying 5,686,000 tons; on a basis of six round trips per annum they could bring a total of 34,116,000 tons of oil to Europe—almost 20,000,000 tons short of the required amount. The tankers flying the flags of other members of the British Empire could do little to make up for this deficiency even were they not needed for maintaining supplies for the various Dominions and Crown Colonies. However, even in times of peace, Britain and especially France have relied to an appreciable extent on Scandinavian tramp tonnage and the Norwegian fleet would greatly assist in making up the shortage with its deadweight capacity of 2,900,000 tons, capable of carrying annually 17,400,000 tons. The Panaman fleet also has tankers which for the most part already operate in European service; these have an aggregate 670,000 tons deadweight which could carry a further 4,020,000 tons. Altogether, annual capacity totaling 55,516,000 tons would be available to transport the 54,000,000 tons required by the allied powers in wartime.

For the countries likely to be ranged on the opposing side in a European war the situation is entirely different. Both Germany and Italy are engaged at the present time in the construction of great hydrogena-

tion plants for the recovery of motor fuel from coal and lignite and for several years have been experimenting in the development of substitute fuels. Both countries have some minor petroleum production of their own and Italy has at its command the output of the Albanian fields. All of these resources combined, however, have been incapable thus far of meeting ordinary requirements. At the beginning of the current year plants then in existence or in course of construction were estimated to have the capacity for supplying roundly half of Germany's domestic needs. With the doubling of requirements resulting from war operations these same plants would be turning out no more than 25 percent of total needs. No doubt there would be a vast concentration of effort directed to increasing the output of synthetic fuels but even so Germany's field operations would be hampered unless she could continue to import gas oil, fuel oil and some gasoline.

Shipments to North Sea ports undoubtedly would be greatly restricted if not cut off entirely. Some supplies might be brought in from the south through Italy and former Austria but access to Italian ports might be as effectively prevented. The nearest important supply that might possibly be made available to Germany by land or river transportation is that of Roumania which might be augmented to some extent from Hungary and Poland.

If Japan and Russia were brought into a general European conflict both countries probably would endeavor to expand their movement of supplies across the Pacific, from California and Mexico. Both have been large buyers on the Pacific Coast of the United States and the only change would be an intensification of this purchasing activity. European Russia presumably could satisfy its own needs by suspending exports but for eastern Siberia it would be easier to draw supplies from overseas rather than attempt to move them overland from established refining points.

Doubts sometimes expressed as to whether the world could supply the petroleum demands of a general European war seem to have little real basis. The actual effect would be to change the routes over which oil would flow to centers of consumption. The movement of oil from Roumania, Russia and Iraq through the Mediterranean probably would come to a halt. Western Europe could no longer rely upon the Near East for the same proportion of supplies now received, but would have to look to America to make up any deficit from the East and to satisfy special war demands. The United States, Venezuela and Colombia are capable of supplying these requirements. Great Britain and France as maritime powers would be able to keep Atlantic trade routes open by use of their navies and indeed would find it necessary to do this to protect the movement of foods and other necessities as well as oil. Central European powers would be handicapped in obtaining supplies from overseas and might find these shut off entirely by an effective blockade. They would have to depend very largely upon synthetic fuels to supplement their small local production. War would put a heavy strain on the petroleum trade and would force consumption up to a new high point, but production is capable of meeting the demand. Difficulties would have to be overcome in moving the oil to the places where it was needed but these difficulties are not insuperable, not at least for those nations that can keep their ports open to commerce and can protect the routes leading to them.

A camouflaged Czechoslovakian tank engaged in recent military exercises.

© Pictures Inc.

In what is written above reference is had to the conditions likely to be created by a protracted war. For the first few months none of the leading European powers would be hampered by lack of oil. All of them have been accumulating large stocks in storage. The exact quantities of course are known only to the military and naval authorities but it probably would sustain operations for a period of six to eight months at most. If the theory that modern warfare is too terrible in its effects to continue for more than a few months is to be accepted as correct no widespread disturbance in the petroleum trade need necessarily result, but experience in Spain and China does not indicate that modern military struggles are likely to be short lived. The chances are that victory finally would be with the side that could longest maintain the supplies of food and oil that are today the essentials of military and naval operations.

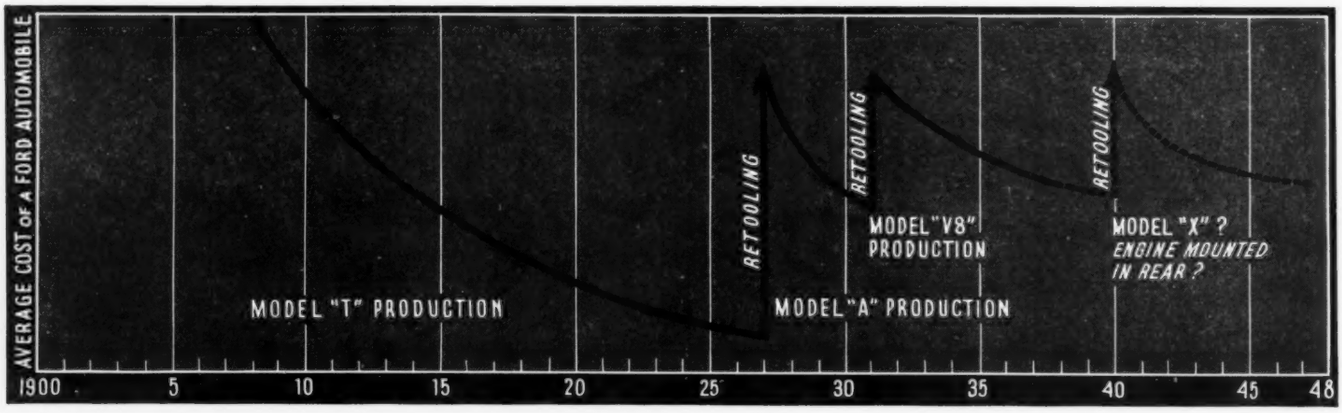


Figure 1a

PARADOX of Exploration Costs

By E. E. Rosaire, Subterrex

RETOOLING has been required in exploration as well as manufacturing. However, manufacturing retooling follows from a decreasing demand in spite of decreasing (production) costs, while exploration retooling follows from an increasing (discovery) cost in spite of maintained or even increasing demand. Thus Henry Ford found it necessary to retool because the demand for his Model T's had decreased materially, although the production cost was then remarkably low; while Gulf Coast exploration was retooled for geophysics because the existent exploration technique (of drilling on surface anomalies) was yielding discoveries only at costs which were prohibitive, even in spite of the increasing price of crude oil.

The paradox, which is not generally appreciated, is that, while retooling in manufacturing is a break from established low production costs to temporarily high production costs, retooling in exploration is a break from established high discovery costs to temporarily low discovery costs. (Figure 1.) Thus, production costs show a continual decrease interrupted only by suddenly increased production costs following the retooling incident to the introduction of a new model, while exploration costs show a continual increase, interrupted only by the suddenly decreased discovery costs following the retooling incident to the introduction of an exploration technique new to a given area.

As an illustration of the workings of this exploration paradox, the following study has been made of the Texas Louisiana Gulf Coast, the so-called salt dome province; the scene of nearly forty years of, at times, intensive prospecting; where, on four successive occasions, the application of an exploration technique new to the area has resulted in marked but temporary decreases in discovery costs with a later return to discovery costs approaching the prohibitive; and yet, where each retooling job has yielded a total of discoveries greater than yielded by any of the previous individual techniques, through the unanticipated attainment of unanticipated objectives.

The discovery record, by years, for the Gulf Coast, is shown in Figure 2.

Three major discovery campaigns are indicated, the first from 1901-1923, the second from 1924 to 1931, and the third from 1932 to date. The operation of the exploration paradox within each period, and from period to period, is discussed below.

FIRST CAMPAIGN

The first campaign was characterized by an exploration technique which consisted of drilling wells upon surface anomalies such as topographic highs, topographic lows, gas seeps, and paraffin dirt beds.

A period of low discovery costs, initiated by the introduction of this technique, was marked by the discovery of Spindletop, Humble, Jennings, Vinton, Sour Lake, Goose Creek and other oil fields in relatively rapid succession. During this period of low discovery costs, while the technique was still new to the area, the original investments were made which resulted, later, in the Gulf Oil Company, the Humble Oil and Refining Company, and The Texas Company, as we know them today.

The later increasing discovery costs, attendant upon the continued application of that same technique, is best described by the following quotation, circa, 1924. "That it becomes increasingly difficult to find additional domes is apparent when we consider that of the forty known domes in the Gulf Coast, thirty-seven were found from 1901 to 1913. Of the other three, two were found in 1917 and one in 1922. Since the discovery in 1917 of the Section 28 dome.....approximately 675 wildcat wells have been drilled in search of new domes on the coast, involving an expense estimated at $20,000,000, exclusive of the cost of the leases and overhead expenses. Yet only one new dome has been found during this period and it has not yet proved profitable commercially as a source of oil."*

In view of these later prohibitive discovery costs, from 1917 to 1923, it is no wonder that no rivals were born then to challenge the Gulf, Humble and The Texas companies today.

SECOND CAMPAIGN

The second campaign was initiated by the retooling in exploration incident to the introduction of geophysical methods of exploration. Two techniques new to the area were introduced, the torsion balance, and the refraction seismograph. In every case, low cost discoveries resulted while each technique was still relatively new to the area, to be followed by increasing discovery costs and a consequent abandon-

*W. F. Henniger, in Geology of Salt Dome Oil Fields. De Golyer and Others, Am. Assoc. Pet. Geol., 1926, p. 776.

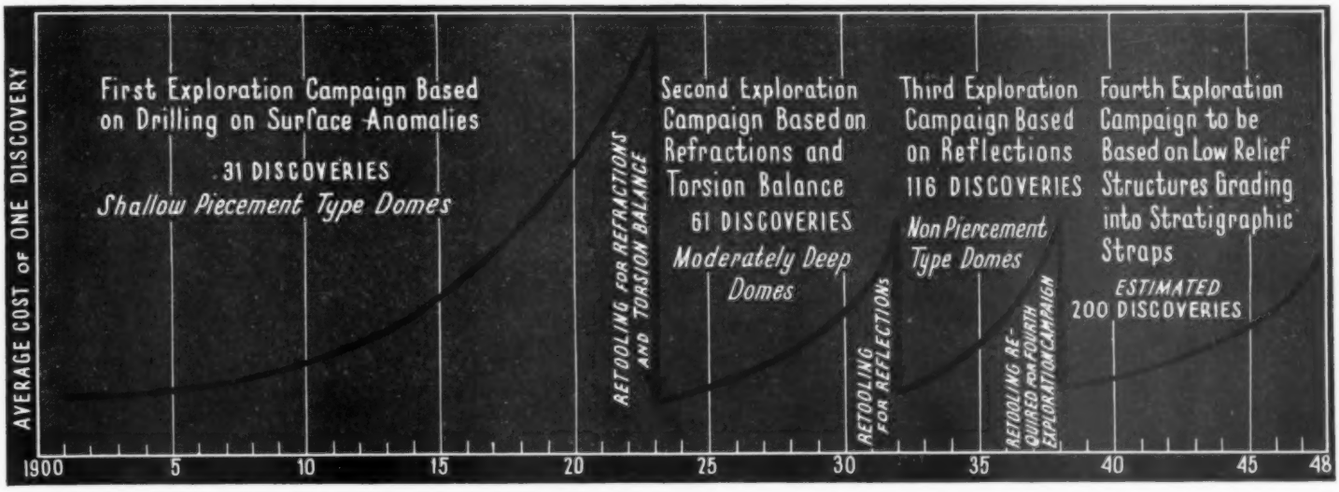


Figure 1b

ment of the technique as a decisive exploration method. Thus, two gravity exploration techniques were successively introduced, the searches for, first, gravity maxima, and second, gravity minima; each made decisive contributions, the former at Nash, Allen, and Clemens, the latter at Sugarland and Thompsons: and each, in turn, was then relegated to a non-decisive role because of increasing discovery costs.

In one of the early refraction crew years, five salt domes were found for the Gulf, by the Seismos, G.M.B.H., (Orchard, Fannette, Starks, Hawkinsville, and Fausse Pointe) following which the discovery rates lagged and the discovery costs rose. Then an improvement in refraction technique, introduced by the Geophysical Research Corporation, another but a minor retooling, made possible the trial of that method in a new area, the lakes and bays of South Louisiana. The resulting discovery rate, of eleven salt domes in one and one-half crew years, is higher than was recorded before or since, and led to a corresponding drop in discovery costs to less than $50,000 per salt dome, only four years after Henniger's figure of $20,000,000 per dome. The introduction of that method into East Texas led to the discovery of one deep (Van) and several shallow salt domes in about two years, another case of lowered discovery costs coinciding with the initial use in an area new to the method.

In spite of these successful operations, the refraction discovery costs rose until the method was abandoned in 1930-1931, after two years of exploration which resulted, primarily, in the discovery of only marginal anomalies and an unduly high percentage of dry holes.

THIRD CAMPAIGN

The third campaign was characterized by the extensive use of the reflection seismograph over the same area previously combed thoroughly in two earlier and quite successful exploration campaigns. Sufficient statistics are available to examine discovery costs for this period in detail. The statistics on reflection crew operations were compiled from the Gulf Coast weekly scout reports, while those on discoveries have been taken from the OIL WEEKLY, Gulf Coast Issue, July 25, 1938, with culling by the writer to eliminate those discoveries in the early part of this campaign wherein, to the writer's knowledge, the reflection technique did not play a material part.

Let us examine the data at hand.

Number of Reflection Crew Years and Discoveries Credited to Them

(A) Year	(B) Crew Years	(C) Discoveries
1930	1.0	0
1931	1.6	2
1932	10.1	2
1933	26.6	2
1934	32.6	9
1935	42.3	12
1936	56.9	20
1937	58.3	34
1938 (Estimated)	(59.6)	(34)

From these data, the curves of Figure 3 are plotted, the lower for crew years each year, and the upper for discoveries each year.

These two curves are quite similar in shape, and show a two year lag of discoveries behind operations. This similarity is even more striking in Figure 4, where are plotted the percentage of each year's operations relative to the previous year's performance. That is, in the lower chart the increase from 1.6 crew years in 1932 to 10.1 in 1933 represents a 531 percent increase in operations, while the increase from 2 discoveries in 1934 to 9 discoveries in 1935 represents a 350 percent increase in discoveries over those for the preceding year (a two year lag).

This conclusion that a two year lag intervenes between the initiation of exploration and actual discovery may appear quite arbitrary, for it, like all averages, is not true of specific cases. Thus, the reflection work associated with the discovery at Manvel in 1931 was not completed until after the discovery well had spudded in. On the other hand, the discovery of oil at Darrow in 1932 was prompted by the reflection exploration made in 1929. The justification for the use of two years as an average lag, is, however, strikingly indicated by the correlation between curves in the charts on page 41.

DIFFICULTY OF DISCOVERY

While curves in Figure 3, together with Figure 4, suggest that discovery is directly related to effort, it is possible to see how closely such is the case by measuring the difficulty of discovery. This index results from calculating the crew years, each year, required for one discovery made two years later. That is, the reflection exploration each year is credited with the discoveries made two years later, using the average two year lag indicated by the curves in Figures 3 and 4.

Index of Difficulty of Discovery

Year	Crew Years	Discoveries Made Two Years Later	Difficulty of Discovery, in Crew Years per Discovery
1930	1.0	2	0.5
1931	1.6	2	0.8
1932	10.1	9	1.1
1933	26.6	12	2.2
1934	32.6	20	1.6
1935	42.3	34	1.2
1936	56.9	(34)	(1.4)
1937	58.3		
1938	(59.6)		

Plotted in Figure 5a, the difficulty of discovery shows a generally steady increase each year, with the year 1933 as a rather outstanding exception of an anomalously high difficulty of discovery, 2.2 as compared with 1.1 for 1932 and 1.6 for 1934.

An explanation for this anomalously high index probably lies in the fact that, in the year 1933, the new crews added to

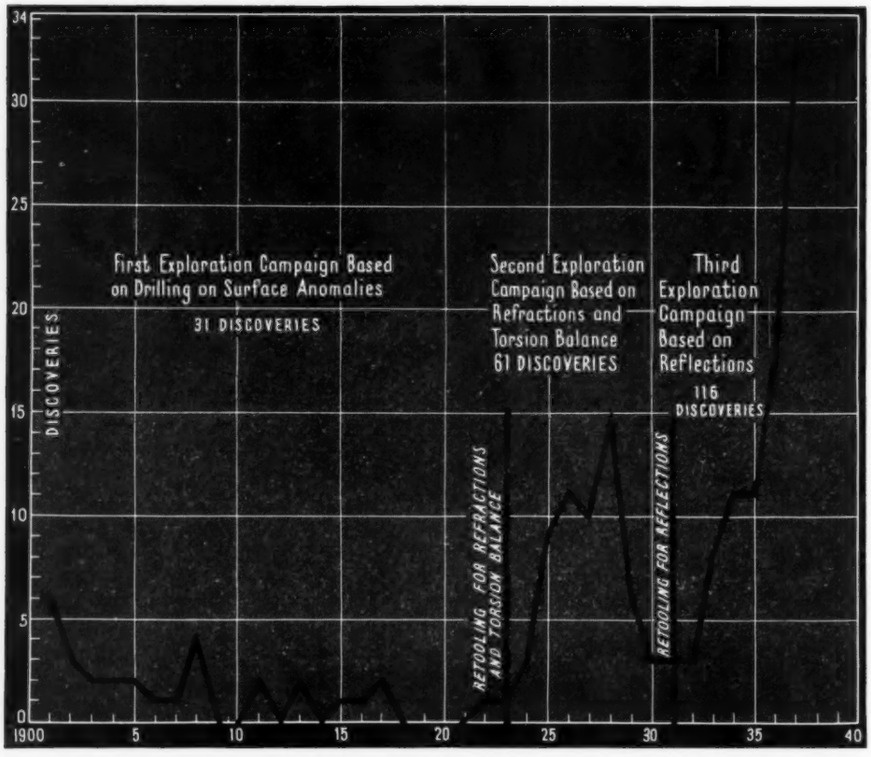


Figure 2

operations in this area were 16.5, definitely higher than in the years 1932 and 1934, when 8.5 and 6.0 new crews, respectively, were added. In only one other year were any such number of new crews added, in 1936, when 14.6 new crews were added. To this highly technical, rapidly expanding, and understaffed industry, this later (1936) large increment was, undoubtedly, less of a strain than was the addition of 16.5 crews in 1933, when the industry was three years younger but only half as old; for in 1930, three years earlier, there were not 16 reflection crews in existence. As a matter of interest, early in that same year, 1933, one operator, without experience in this technique and who had partialy mapped the uplift at Hastings, failed to recognize the evidence for uplift, actually shown on his records, because of his inexperience in interpretation and his lack of confidence in a newly designed and built set of apparatus. Six months later, another operator, with more experience and confidence in that same technique, independently re-discovered the uplift for the Stanolind Oil and Gas Company.

Obviously, there is something to be said for experience, particularly when a technique is relatively new and is expanding under highly competitive conditions.

COST OF DISCOVERY

For each exploration campaign, it is generally bemoaned, but not generally recognized as something to be expected, that unit exploration costs increase with the passage of time. Thus, the reflection crews operating in 1932 used five geophones, hand dug shot holes, and six to eight men, while those operating now use more geophones (as many as 64 and 96 have been reported from individual crews), machine dug shot holes, and, frequently, more than 20 men. While the quality of the data has improved during that period, the operating cost per crew month has also increased, from about $6,500.00 in 1932, to over $9,000.00 in 1938. During that period, the actual coverage per month has diminished considerably, due to the fact that continuous profiling has become a standard technique and is required to find the low relief anomalies now generally found today. So, starting with a crew year cost of $80,000.00 in 1932, a yearly increase of $5,000.00 per crew has been considered not out of line, yielding the accompanying schedule of exploration costs for each discovery.

Exploration Cost Per Discovery

Year	Cost per Crew Year	Crew Years for Discovery	Exploration Cost of of Discovery
1930	$80,000.00	0.5	$40,000.00
1931	80,000.00	0.8	64,000.00
1932	80,000.00	1.1	88,000.00
1933	85,000.00	2.2	187,000.00
1934	90,000.00	1.6	144,000.00
1935	95,000.00	1.2	114,000.00
1936	100,000.00	1.4	140,000.00
1937	105,000.00		
1938	110,000.00		

We see, then that, except for the year 1933, and also 1934, the cost of discovery has increased nearly four times from 1930 to 1936. It is also of interest to note that 30 discoveries in 1939, and 30 again in 1940, will be required to keep the cost of the exploration work done in 1937, and being done in 1938, below $200,000.00 per discovery. Should the discoveries in 1940 fall to as few as 11, then the reflection exploration now going on will have been done at the rate of $500,000.00 per discovery.

While the difference in cost, between $40,000.00 and $150,000.00 or more, per discovery may be considered negligible in comparison with subsequent development costs, or with the difference in the individual recoveries established later, one should not lose sight of the fact that had that nearly $150,000.00 per 1936 discovery been invested six years earlier, not only would more discoveries have been realized, but those discoveries would have been in the relatively more obvious class, of which Iowa, Manvel, LaFitte, and Hastings are typical, rather than in the less obvious class now being found, of which Satsuma, Tepetate, Eureka, and Sandy Point are examples.

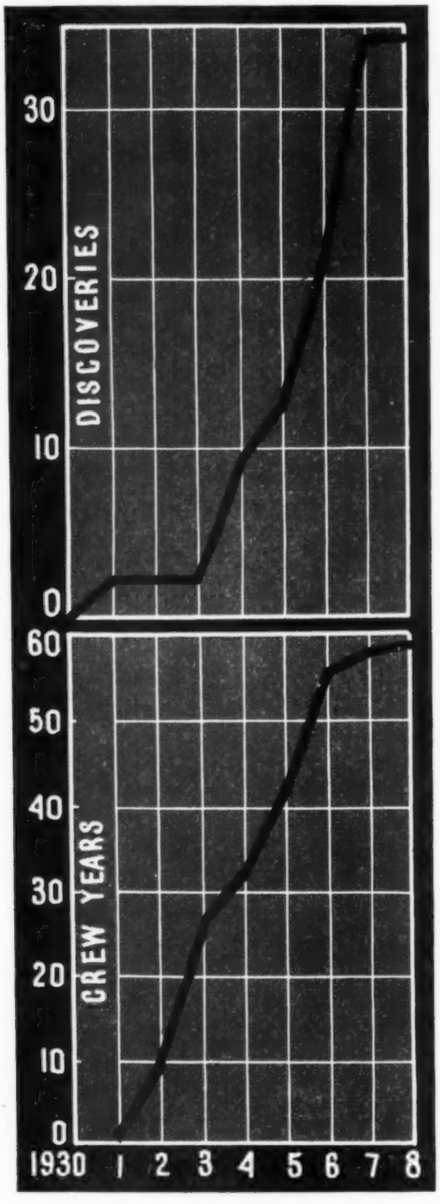
It is of interest to look for reasons why a decrease in discovery costs should follow a successful exploration retooling. First of all, it is obvious that success increases the hazard of future discoveries, by reducing the number of discoveries which can be made later. Second, the more obvious discoveries generally will be made while the technique is still relatively new to the area, leaving the less obvious to be found by the later, even though more proficient, technique. Third, and most important, is that an exploration retooling need not, in fact, should not, start from scratch, but should be applied first to the prospects indicated marginally but inadequately by the previously used methods.

In general, the life of any exploration technique in a given area is characterized by two stages of finding power, or discovery cost. The initial, low cost, period is the prospect evaluation priod, characterized by the use of the new technique to re-examine the marginal and submarginal prospects placed on record by the previous methods in their later stages of low finding powers and high discovery costs. After all such prospects have been re-examined by the (now relatively) new technique, then the discovery of new prospects follows only from blanket exploration by that same technique, which in turn then experiences a natural and consequent increase in discovery costs.

These general and specific examples illustrate the paradox of exploration, in that discovery costs increase with the continued use of a method, and decrease with the retooling associated with the introduction of a method new to the area. Considering the rising discovery costs in this area now being exhibited by reflection exploration, it is of interest to examine the situation for the possibilities of a reduction of discovery costs by a fourth retooling.

An examination of Figure 1 shows that each period of discoveries has resulted in the discovery of more oil fields and domes than the previous period. Thus, in the first campaign, 31 discoveries were made, in the second, 61, and in the third, 116 to date. Though not at first obvious, these successive (total) increases have been attained by the discovery of structural closures of decreasing relief. Thus, the first period was characterized primarily by the discovery of shallow piercement type salt domes; the second by the discovery of the moderately deep salt domes; and the third, primarily, by non-piercement type domes and structures, with reliefs as low as 100 ft. or less. That is, an increasing number of structures have been found as the differential uplift discernible has decreased. In other highly prospected areas, the same tends to be true, as in the Mid-Continent, where the Oklahoma City type of structure is the exception rather than the rule.

Figure 3



Then, on the basis of past experience, if a successful retooling job can be accomplished, once again, in this highly prospected area, it is reasonable to expect that an even greater number of still lower relief oil fields will be discovered thereby than were discovered in the immediately preceding (i.e., present) period of discovery. However, our present structural prospecting methods are based upon differential depth measurements for the recognition of structure; and if the relief to be expected is less than that now being found only with difficulty by these methods, then either our present methods must be improved so as to measure differential depths in inches rather than feet, or some other properties of structure must be used as bases for recognition and discovery.

The direct approach, of course, lies in further material improvement in the method now being used, a task which, while not impossible, will be, very probably, difficult to achieve. A possible comparison might be in the attempt to improve long distance acoustic communications by improving the vocal abilities of hog callers, in comparison with the indirect approach of developing an entirely new means for acoustic communication in the way of the telephone. The indirect approach, in the case of structural prospecting, would be to make use of properties of structure which are not dependent upon relief. Such procedure would not be, inherently, a backward step, for the ultimate production from a structure is not even a consistent, let alone a direct, function of relief. The really big oil fields of the world, Levorsen's "elephant pools," are structures of zero relief, i.e., stratigraphic traps.

One such property of structure, observed but not fully recognized in the past, is the fracturing and jointing in the overlying beds which results from their elongation when arched or bowed. The fracturing which follows apparently can result even from the minute elongations resulting from differential compaction over sand lenses embedded in matrices of shale, and so is related, not to the relief, but rather to the areal extent of the underlying structure. Generally the displacement, if present at all, of the individual fissures is extremely small, so that their existence is difficult to establish directly, but their presence is required to account for the shallow phenomena so frequently observed at shallow depths over structures of even low relief.

Surface seepages of oil and gas have long been recognized as important clues to the location of favorable structures. In the past, the detection of such seepages has been macroscopic, i.e., visible, and, in the case of gas seepages, generally limited to water covered areas. Just as micropaleontology has developed into a more widely used and more useful method than macropaleontology, so the recently developed technique for recognizing microscopic leakage bids fair to be a more widely used and more useful method than the earlier technique of searching for visible seepages of oil and gas. The development of this new technique was initiated by Laubmeyer with his soil gas analysis in 1928, carried on by Sokolov and his Russian associates from about 1931 until the present, and has also been under study in the United States of America in many geochemical laboratories. A more promising development in this technique has been the analysis of the surface soils for adsorbed traces of leaking hydrocarbons, which, in the case of microscopic leakage, apparently yields more quantitative results than does the analysis of the soil gas alone.

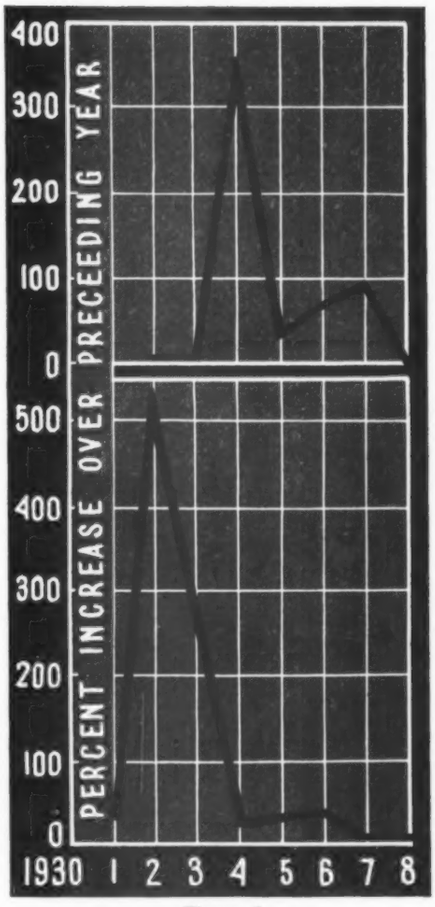


Figure 4

Evidence for the presence of secondary mineralization in the beds overlying buried structure has been observed in at least four different ways; mechanically, in the form of induration (the so-called "dome digging" of a generation past, quite obvious before the introduction of dreadnought rigs and rock bits); acoustically, or seismically, in the form

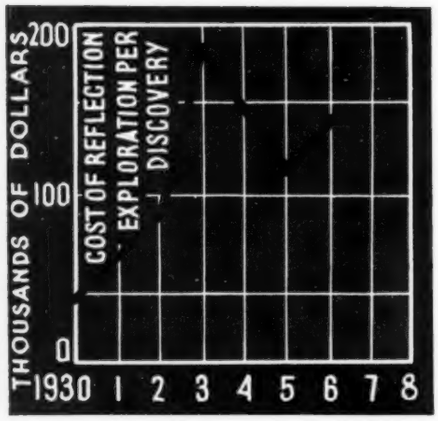


Figure 5b

of the increased seismic velocities observed over structure in the Gulf Coast and Permian Basin; electrically, in the form of the anomalies found by the electrical transient (Eltran) method recently invented by Blau; and chemically, in the accentuated surface leakage of hydrocarbons, which indicate buried structure by a "halo" or "aureole" pattern, a phenomenon observed a generation ago in the Gulf Coast and recently rediscovered by the writer and his associates.

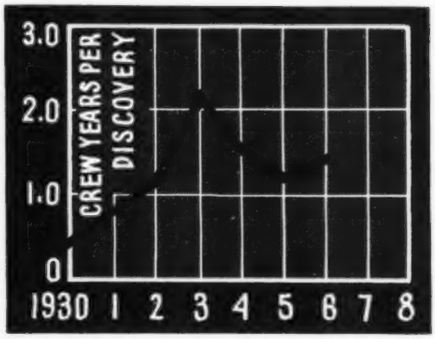
Since this property of buried structure is related to the areal extent of the buried structure rather than to the differential relief at depth, its recognition should be of particular importance in all petroliferous provinces which have been subjected to prospecting by methods dependent upon the determination of differential depths (i.e., in those areas where the reflection seismograph is now yielding discoveries at prohibitive costs), and might properly be called stratigraphic rather than structural prospecting. As we consider structures of less and less relief, their gradation into true stratigraphic traps (structures of zero relief) many may be such as to permit drawing no line of demarcation, but to the extent that differential compaction plays a part, this lateral property of structure, in one or more of its several manifestations, presents promise of being of material assistance in the search for true stratigraphic traps.

CONCLUSION

In conclusion, it can be said, quite reasonably, that;

1. Ford manufacturing costs will not approach those for the Model "T" if manufacturing retooling is effected at too frequent intervals.
2. Discovery costs will not approach those for the Gulf Coast from 1917-1923 if exploration retooling is effected at sufficiently frequent intervals.
3. After 40 years of intensive structural prospecting based on the differential depth determinations, the undiscovered oil fields, in many important petrolifreous provinces, are characterized by relief comparable with the observational errors of those methods, resulting in increasing, and often prohibitive, discovery costs.
4. Exploration retooling is required to bring discovery costs again within reason in those petroliferous provinces, and such retooling should be directed at the recognition of some other property of structure besides relief. The evidence at hand for the existence of a previously unrecognized property of structure, which emphasizes lateral extent rather than vertical relief, offers a most promising means for initiating the indicated retooling in the form of stratigraphic rather than structural prospecting.
5. Since there is evidence to show that the number of possible structures increases as the relief decreases, and also, since the really big oil fields of the world are stratigraphic traps (structures of zero relief), such a retooling for stratigraphic prospecting yields promise of locating reserves of appreciable importance.

Figure 5a



Britain Imports Less Fuel Oil

FURTHER reduction in imports of fuel oil are an outstanding feature of British petroleum import trade for August. Total for the month was 1,269,000 bbl. compared with 2,279,000 bbl. for the corresponding month of last year. Imports of fuel oil have now declined for two consecutive months, the figure for June last being 1,861,000 bbl., a falling off which is hardly likely to be due merely to the incidence of shipments.

No tax change was made in the last British Budget likely to check consumption of petroleum products classified under the heading of fuel oil, and the smaller shipments now being received are probably a reaction from the heavy imports made earlier in the year. This suggestion is supported by the fact that imports of this class for the eight months to August 31, at 14,042,000 bbl., still show an increase on the total imported during the same period of last year.

Expansion of imports of refined products from the United States is notable, particularly in the case of kerosene and lubricating oil. Eight months' shipments of lubes from America, at 1,788,000 barrels, account for over 80 percent of total British imports of this product.

British Oil Imports By Products

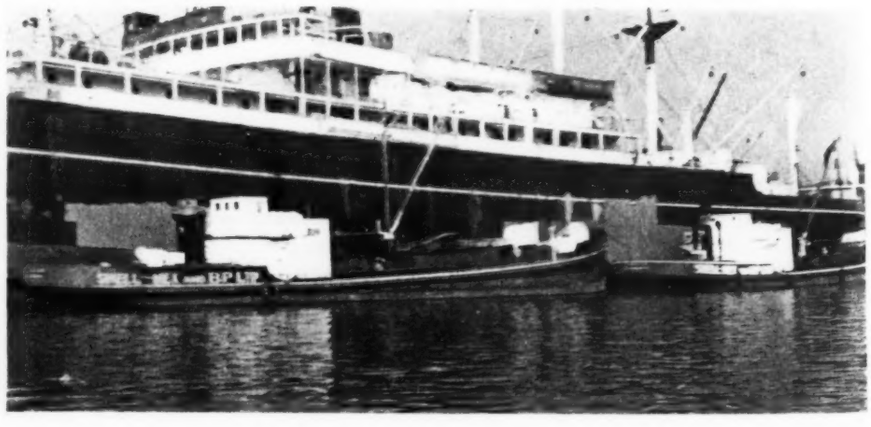
(Barrels)

	August 1938	8 Months to August 31 1938	8 Months to August 31 1937
Kerosene	586,000	4,146,000	4,057,000
Motor spirit	3,494,000	27,802,000	27,480,000
Lubricating oil	210,000	2,215,000	2,204,000
Gas oil	605,000	3,292,000	2,757,000
Fuel oil	1,269,000	14,042,000	13,438,000
Other sorts	31,000	376,000	293,000
Total products	6,195,000	51,873,000	50,229,000
Crude	1,625,000	11,703,000	10,090,000
Total imports	7,820,000	63,576,000	60,319,000

Aggregate of all British petroleum imports for the eight months at 63,576,000 bbl., is 5.4 percent above the 1937 figure. All the main categories contributed to the rise, the increase being particularly marked in crude imports, which rose by 16.0 percent.

Bunkering a liner with fuel oil on the River Thames, England.

Photo by H. Leslie Gough



25 YEARS of Oil in Czechoslovakia

By Dr. Th. Novak and Rudolf Seiden

PETROLEUM has been produced since 1913 in the region that is now Czechoslovakia. The first find was at Egbell (or Gbely) in Slovakia and this field is still the largest producer; it is state property. After the World War a second field was found at Goding (or Hodonin) in Moravia, and was acquired by a French concern, the "Apollo" Mineral Oil Refinery Company of Bratislava. More recently a third field was opened at Vacenovice, also in Moravia, which yields only gas used chiefly for lighting purposes. Aside from these relatively important sources there are several smaller fields at Bohuslavice, Turzovka and Mikowa, which are of local importance. Still more recently new deposits of oil have beenfound at Watzinowitz (much gas was encountered along with oil), Zborowitz and Sokolnitz in Moravia, which have raised hopes that Czechoslovakia might be able soon to produce considerable amounts of oil.

The Egbell and Goding deposits are in Sarmatian formation, which was laid down in an extensive brackish water lagoon. Above the Sarmatian is the Pannonian, which was deposited in a sea that covered large portions of Central Europe. At Egbell the oil horizon is found at a depth of 525 ft., in Goding at 460 ft. The newer wells in Egbell reach a maximum depth of 850 ft. where they penetrate an oil sand that is six to 46 ft. thick. The annual production is about 12,000 tons (80,400 bbl.) of a heavy, non-paraffinic oil which contains practically no light ends. The principal refined product is a lubricating oil of low or medium quality.

In Goding the wells go down as far as 2,950 ft. Drilling is comparatively active at a rate of about 40,000 ft. per annum. The yearly production is about 10,000 tons (67,-000 bbl.). There are two distinct oil horizons, an upper one where the oil is non-paraffinous and even heavier than at Egbell (sp. gr. 0.940-0.950) 19-17 deg. A.P.I., and a lower one yielding a lighter oil like that found at Zistersdorf in Ostmark, (Austria); this oil contains a little gasoline and some kerosene and paraffin. It also yields a somewhat better lubricating oil.

As a world oil producer, Czechoslovakia ranks 28th, just ahead of Italy; in Europe it ranks fifth, just behind Ostmark. In 1937 the total production of the whole Republic was 122,790 bbl., compared with 126,603 bbl. in the preceding year and 177,797 bbl. in the record year of 1934.

It would undoubtedly be possible to increase the oil production of Czechoslovakia considerably in view of the fact that oil reserves in the proven territory and the many favorable prospects must amount to several million tons. If in spite of this fact the industry has developed slowly, the reason is that the government itself is set against a too rapid extension of drilling, which could easily result in ruthless exploitation.

At present the country's needs can easily be covered by imports. The purpose of the government eivdently is to conserve the country's oil reserves against a possible time when imports of foreign oil products may be cut off by a hostile blockade. In view of the geographical situation of the Czechoslovak Republic, with no seaport of its own and surrounded by powerful and none too friendly neighbors, perhaps the government's course is justified.

In 1937 the importation of crude oil into Czechoslovakia amounted to about 460,-000 compared with 403,000 tons in 1936; at the same time the domestic production was only 3.9 and 4.6 percent of this amount respectively; in 1934 the domestic production was 7.3 percent of imports, a high point. In war time (assuming that the country is not overrun) production could be multiplied many times and maintained for many years, and if necessary could be supplemented by production of synthetic oils, which is being intensively studied.

As a matter of fact, the Government has passed no law expressly prohibiting expansion of oil production, but effects the purpose by simple tax legislation: companies drilling for oil are not allowed to deduct money spent on wildcat wells from their tax balances. On the other hand lavish favors are bestowed on the oil refineries.

In 1937, of the 460,000 tons of total imports, 224,000 tons were crude oil, 153,000 tons were crude distillates; the rest included various finished products among which were 14,400 tons of finished gasoline and the surprisingly small amount of 1,625 tons of lubricating oil. Corresponding figures for 1936 were: total imports, 403,000 tons; crude oil, 163,000 tons; crude distillates, 162,000 tons; finished gasoline, 19,100 tons; and finished lubricating oil, 1,943 tons. This low importation of lubes is explained by the fact that the native oils, which are free from paraffins, can be used for lubrication purposes after simple and inexpensive treatments, or even directly.

While the tariff on refined products is comparatively high, the importation of crude oil, or a crude gasoline distillate mixed with five to 15 percent of crude oil, is duty free. The greater part of mineral oil imports comes from Roumania, which in 1937 furnished 338,000 compared with 260,000 tons in 1936. Other suppliers are Poland and the United States; the latter country supplied only 40,000 tons, while in recent years Russia has sent practically nothing.

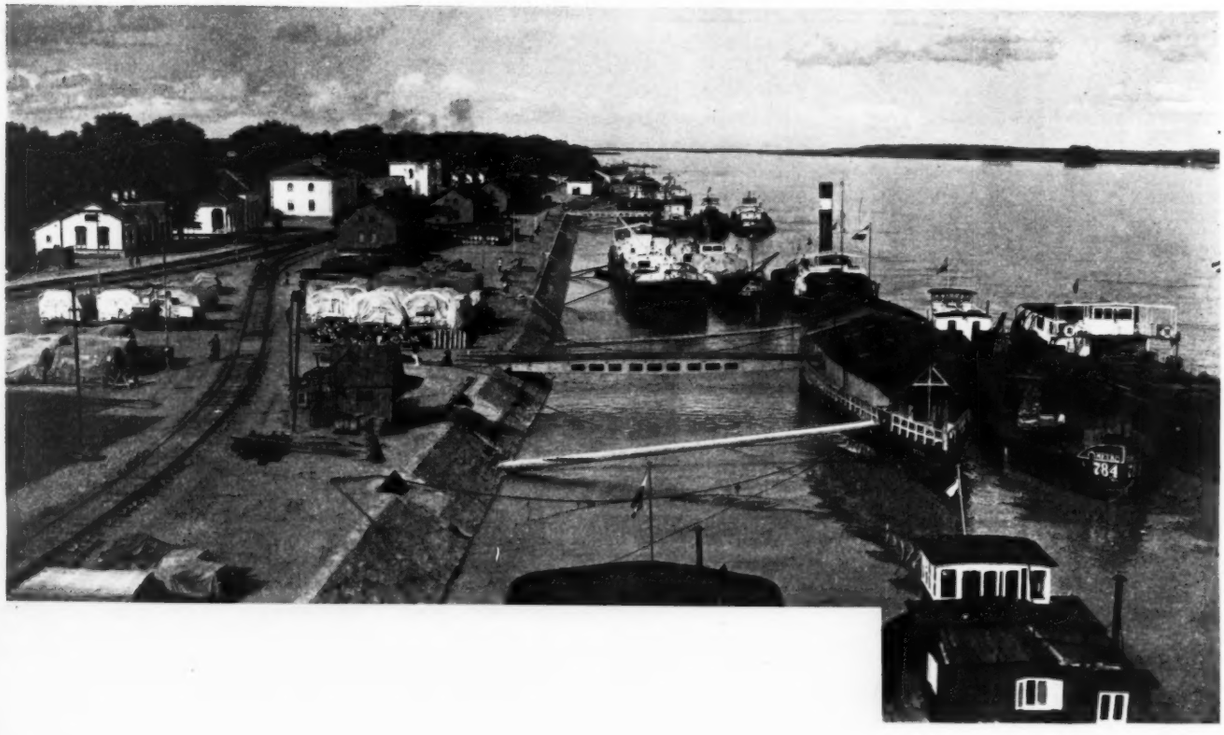
At the present time the total investment in the Czechoslovak oil industry amounts to about $17,500,000, of which 60 percent is in refineries, 20 percent in retail trade, and 10 percent each in the wholesale trade and in production. The refineries have a total capacity for working 1,000,000 tons a year, but only a relatively small proportion of this capacity is utilized. The annual consumption of motor fuel is about 250,000 tons, which includes 200,000 tons of gasoline, a little more than 40,000 tons of alcohol and nearly 10,000 tons of benzol. Eighty five percent of the total consumption of mineral oil products is controlled by a cartel, the "Sdruzeni Czechoslovenskych Rafinerii Mineralnich Oleju." The following refineries are now operating: (see page 45)

Fantowerke A.G., Pradubice; "Odra" Mineral Oil Co., Novy Bahumin; "Vesta" Slovakische Mineral Oil Co., Tostena; "Apollo" Mineral Oil Refinery A.G., Bratislava; Vacuum Oil Co., Kolin; "Kralupska Raffinerie" Lederer & Co., Kralupy; "Privoz" Mineral Oil Co., Privoz; "Priemyselna a Obchodna uc.spol." Straszke; South Carpathian Oil Refinery and Verkaufsgesellschaft, Mukacevo; Anton Himmelbauer and Co., Mihalany.

A few months ago the "Apollo" brought into operation at Bratislava a new plant for making knock-proof gasoline from domestic oil; this plant cost 20,000,000 kc. The government itself has finished construction of a modern oil refinery at Dubova near Banska Bystrica, Slovakia, as remote as possible from the frontiers; this plant will refine chiefly domestic oil produced in the Egbell field. Although no information as to the capacity of this plant has been given out, from a personal inspection by one of the authors it appears capable of turning out 56,000 tons of gasoline, 14,000 tons kerosene, 7,000 tons or more of gas oil, 7,500 tons lubricating oil and more than 6,000 tons asphalt per year. On this basis it seems that this plant alone can supply a fourth of the total demand of

Powerful tugs are necessary to tow up-stream traffic through the strong current of the cataract region, Kazan Pass.

ROUMANIAN OIL ON THE DANUBE



The port of Giurgiu was once the scene of great activity, but decreased purchases of refined products by Austria, Hungary and Germany together with decline in crude oil output have resulted in almost a cessation of Roumanian petroleum traffic on the Danube.

Based on the details of production for the first eight months of this year, the 1937 output will be lower than it has been in the past five years.

Roumanian Oil Production

Year	Barrels
1937	52,176,000
1936	63,532,846
1935	61,270,072
1934	61,849,306
1933	53,919,708
1932	53,651,978

the country. Apparently, the government intends to increase production in the Egbell field.

In this connection mention may be made of the two coal liquefying plants that are now under construction in Czechoslovakia, which are the outcome of ten years of technical and financial preparation. Both these plants are located as far as possible from the German and Polish frontiers, one at Krickerhau, which is scheduled to produce 30,000 tons of gasoline a year, the other at Navaky, capacity not stated.

For many years no straight gasoline has been used as motor fuel in Czechoslovakia; the motorists are obliged to take a mixture containing 20 percent of alcohol (from potatoes and grain) at a cost equivalent to 40 U. S. cents a gallon; 40 percent of this price is chargeable to alcohol and only 14 percent to gasoline, which constitutes 80 percent of the mixture, 25 to various taxes, 12 percent for import duty, leaving 9 percent for freight, distribution costs and profit. These figures relate to a motor fuel made in the country from imported crude oil. The profit is still less if imported gasoline or imported alcohol are used. Hence most of the business is founded on imported crude.

In summary it may be said that Czechoslovakia is not rich in oil but will certainly have enough for its own use in war time, and with the assistance of home-made synthetic oil could hold out for a long time. The policy of the government is to make imports of finished products difficult so as to favor the development of a domestic refining industry. This industry is much larger than corresponds to the needs of the country; nevertheless, new refineries are being erected, because the older ones are located too near the German and Polish frontiers for safety in war time. This has marked the province of Slovakia as the new seat of the Czechoslovak oil industry.

Post-War Oil Consumption in ROUMANIA

By Ing. C. Osiceanu, President Assoc. Petroleum Industrialists of Roumania, and Gen. Mgr. of Steaua Romana

DURING the last 15 years of the post-war period, Roumanian oil consumption has increased steadily—from 765,794 tons in 1923 to 1,620,678 tons in 1937. This increase is attributable to progress in motor traffic, industrial development, mechanization of agriculture, development of central heating, and the new uses found for certain products.

By continuous extension of sales depots to the present level of about 1,100 the oil companies have contributed to the development of consumption. Refineries have improved the quality of their products, reduced the cost of manufacture and lowered the selling price.

Roumania is far from reaching the saturation point of the domestic market for petroleum products. Due to creation of new private and state industries, there is the possibility of intensifying motor traffic, electrification of the country, and perfection of agricultural mechanization.

It is suggested that the following measures should be taken by the Roumanian state for development of domestic oil consumption: (1) reconstruction of roads; (2) relieve the petroleum industry from the heavy fiscal charges which it has to support; (3) electrication of towns and villages, lighting of major roads; and (4) simplification of the formalities required for the creation and operation of marketing depots.

Out of 65,000 mi. of regular roads some 9,000 mi. only are fit for motor traffic. With a population of 19,500,000 Roumania has about 93,000 motor vehicles (only one for 591 inhabitants); the gasoline consumption of 133,000 tons in 1937 gives an average of 6 kg. per inhabitant. This compares with the United States, which where the proportion is one motor car to four inhabitants and consumption 484 kg. per person. Special attention is now being given to reconstruction of the roads by the state.

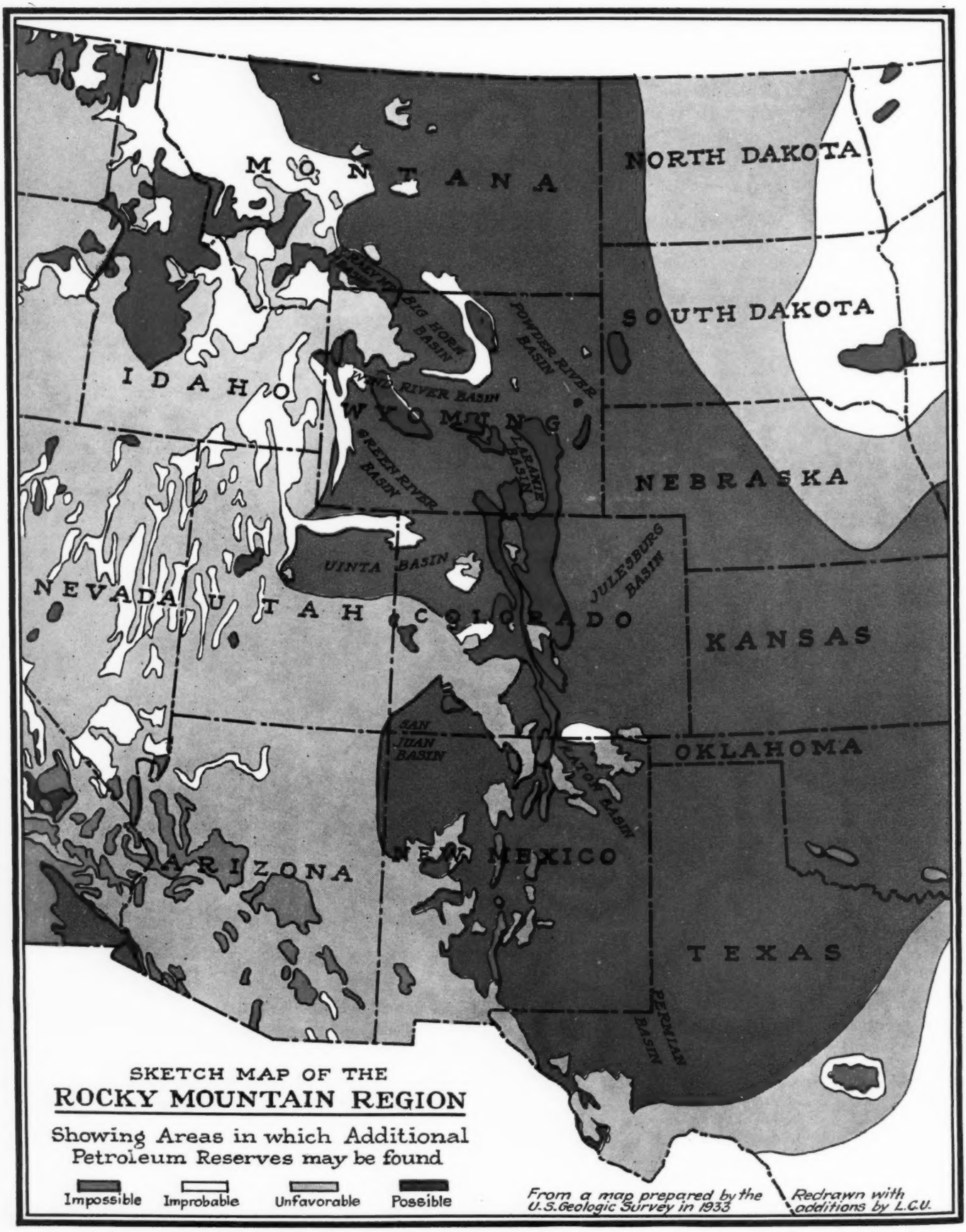
In the interests of national defence it will be necessary to construct domestic factories for manufacture of automobiles and accessories, so as not to be dependant upon other countries.

For the realization of this desideratum, the assistance of the state is necessary to stimulate private initiative by granting fiscal facilities and exemption from duties.

Heavy consumption taxes borne by the petroleum industry are an impediment to development of consumption. In 1937, on a consumption of 1,620,678 tons, valued at Lei 3,651,135,000, the total taxes payable in different forms to the state and municipalities amounted to Lei 2,540,110,000, or about 70 percent. Gasoline, which is sold ex refinery inclusive of taxes at Lei 10.30, is taxed Lei 8.30 per kg., or four times as much as the ex refinery value. The same is true of gas oil and lubricating oils. Taxes on fuel oil and coke should be suppressed altogether, since natural coal and wood do not have to support similar taxes.

New power stations created through the introduction of electric lighting, in all towns would appreciably increase consumption of fuel oil. In rural districts, where electrification would take several years, temporary illumination could be by kerosene lamps—each burning six hours nightly and consuming 45 litres per annum at a cost of about Lei 160.

Creation of new marketing depots requires a series of formalities to obtain the necessary authorizations from four different government departments. The Mining Law of 1937 theoretically simplified these to permission from the Ministry of National Economy only, who consults the other authorities. Different interpretations of the text, however, makes it still necessary to obtain permission from the others.


MONTANA
NORTH DAKOTA
SOUTH DAKOTA
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
OKLAHOMA
ARIZONA
NEW MEXICO
TEXAS
BIG HORN BASIN
POWDER RIVER BASIN
GREEN RIVER BASIN
LARAMIE BASIN
UINTA BASIN
JULESBURG BASIN
SAN JUAN BASIN
PERMIAN BASIN
SKETCH MAP OF THE
ROCKY MOUNTAIN REGION
Showing Areas in which Additional Petroleum Reserves may be found
Impossible
Improbable
Unfavorable
Possible
From a map prepared by the U.S. Geologic Survey in 1933
Redrawn with additions by L.C.U.

ECONOMICS AND GEOLOGY of the Rocky Mountain Area III

By Prof. L. C. Uren

Third Installment of Prof. Uren's Exhaustive Study of the Oil and Gas Fields of the Rocky Mountain Area Made for World Petroleum.

PRODUCTION methods employed in operating oil and gas properties in the Rocky Mountain region are not unlike those of other districts. Most of the wells are comparatively shallow and their operation presents no unusual problems. In the shallower territory, groups of wells are frequently pumped in multiple from central powers with shackle lines and jacks. Where wells are too widely spaced, too deep or too erratic to operate by this method, they are individually pumped on the beam or with pumping units. During early life, many of the wells flow their production, particularly in the deeper territory now being exploited. High reservoir pressures in the deeper producing formations permit of retaining more gas in solution in the oil and consequently production is better sustained from these deep reservoirs and higher percentage recoveries are secured than from the shallower horizons. As in fields in other regions, gas-lift is useful during a certain stage of productivity, intermediate between the period of free flow and the period of mechanical pumping.

PRODUCTION METHODS

In some of the older fields, rather primitive production equipment is observed, but in some of the more recently developed fields, equipment of the most modern type is installed, with steel production derricks, tubing hoists, pumping units, steel flow tanks and efficient gas traps. In some areas operators prefer water-top wood-stave flow tanks. While much water is produced with the oil in many of the older fields, it separates readily from the lighter oils without necessity for special treatment. Dehydration will probably be a factor of greater importance when the fields producing the heavier black oils are more intensively exploited.

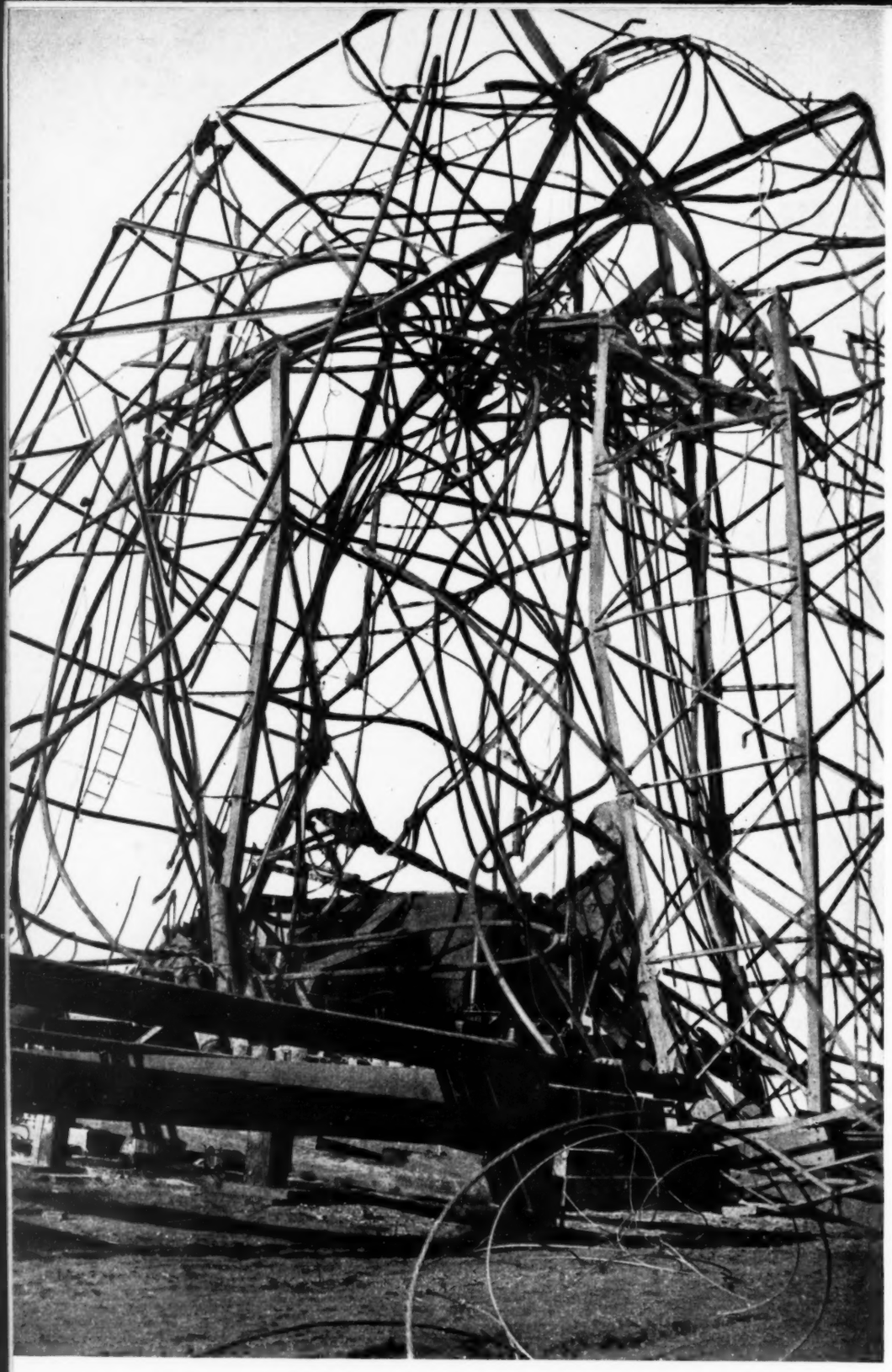
Operators in the more recently discovered and developed fields are utilizing modern methods of pressure control designed to reduce gas-oil ratios and increase production efficiency. In this work they are being aided by U.S. Geological Survey and U.S. Bureau of Mines technologists, who have given much attention to studies of gas conservation, decline of reservoir pressures and characteristics of oils and reservoir rocks. The Geological Survey and Bureau of Mines are collaborating in preparation of a comprehensive technical report covering operating and subsurface conditions in all of the important fields of Wyoming and Montana. In earlier years, oil producers of the region have been aided by detailed studies of paraffin accumulation in wells and equipment and methods of paraffin control, also conducted by U.S. Bureau of Mines technologists. Most of this work has centered at the Laramie, Wyoming, experiment station of the Bureau of Mines and the Midwest, Wyoming, Laboratory of the U.S. Geological Survey.

Where production is secured from limestone reservoir rocks, acid treatment of wells has been beneficial in stimulating the rate of production and ultimate recovery. Acidizing of wells has been particularly effective at Hobbs and other fields in south-eastern New Mexico where production is from the White Lime of that region; and in the Kevin-Sunburst field of Montana, where oil is secured from the Madison Lime. Remarkable success has attended acid treatment in the Kevin-Sunburst field, some of the old wells apparently nearing exhaustion, being recompleted after acid treatment with production rates in excess of their initial productions. In earlier practice, wells producing from limestone reservoir rocks were often shot with high explosives.

Gas engines are widely used in furnishing power for pumping operations, electric power being not generally available in most of the producing areas. A notable exception to this statement however, is found in the Salt Creek Field of Wyoming, where as previously noted, a 25,000-k.w. generating plant furnishes electric power.

Secondary recovery methods have not been extensively employed in the Rocky Mountain region up to the present time, as most of the fields have not yet declined to a point where such methods are necessary. However, some gas injection has been practiced in a number of the older fields, particularly in the Salt Creek, Labarge, Rock Creek, Lost Soldier, Elk Basin and Grass Creek Fields. Percentage recoveries by primary exploitation methods will be low in most fields, leaving a large percentage of the original oil content of the reservoirs partially available for future recovery by secondary methods. Of the several secondary methods that might be used, gas injection would appear to be the most readily applicable at the present time, though conditions are not unfavorable for water-flooding in some fields. Use of vacuum as a means of stimulating production has been found detrimental in cases where it has been tried in the Rocky Mountain fields, operators claiming that it tends unduly to increase the gas-oil ratio and gasoline content of the gas and to decrease the gravity of the crude. Though there is a slight temporary increase in the rate of oil production, this is in time compensated by a more rapid increase in the rate of decline.

Production control is not a matter of great concern to operators throughout most of the producing fields of the Rocky Mountain region. Proration is unnecessary in most of the older fields where the potential capacity of wells to produce has diminished to low levels. In some cases, entire fields are controlled by single operators, so that the economic forces of supply and demand can determine the rate of production. In some of the more prolific fields now in flush production, operators have entered into voluntary agreement to regulate production in accordance with the dictates of an umpire or a representative operators' committee. In the Lea County, New Mexico, fields for example, one of the most effective and best administered proration organizations in the country regulates the output of all operators on an equitable basis. In New Mexico, general administration of oil and gas conservation laws is entrusted to a state Conservation Commission, which maintains a field office at Hobbs with a competent engineering and geological staff in immediate charge of all matters relating to enforcement of the Commission's conservation regulations. The State of New Mexico is a party to the Federal Interstate Compact, but proration matters in the Lea County fields are in charge of an umpire, who maintains an office and technical staff at Hobbs and has



Wreckage of steel derrick and drill pipe, occasioned by gas blow-out in the Hobbs Field, New Mexico; 2,000 ft. of drill pipe were blown 500 ft. above the ground.

effectively controlled the output of all fields in this district since 1930. The Conservation Commission and umpire's organizations have greatly assisted the operators in this district in achieving an orderly programme of development and exploitation and an equitably-shared output that has been kept closely in accord with the market demand. In the Lance Creek Field of Wyoming, an unofficial working agreement among the major operators restricts output to accord with market outlets, and efforts have also been under way for some time to unitize the Salt Creek field. In the Kevin-Sunburst and Cut Bank fields of Toole County, Montana, an effective proration programme has controlled output under the auspices of the Oil Conservation Board of the State of Montana. Offices and technical personnel are maintained for this service at Great Falls, Montana.

TABLE III

Petroleum Production in the Rocky Mountain States*

Year	Thousands of Barrels			
	Montana	Wyoming	Colorado	New Mexico
1912	.....	1,572	206	.....
1913	.....	2,407	189	.....
1914	.....	3,560	223	.....
1915	.....	4,246	208	.....
1916	45	6,234	197	.....
1917	100	8,978	121	.....
1918	69	12,596	143	.....
1919	90	13,178	121	.....
1920	340	16,831	111	.....
1921	1,509	19,333	108	.....
1922	2,449	26,715	97	.....
1923	2,782	44,785	86	.....
1924	2,815	39,498	445	98
1925	4,091	29,173	1,226	1,060
1926	7,727	25,776	2,768	1,666
1927	5,058	21,307	2,831	1,226
1928	4,015	21,461	2,774	943
1929	3,980	19,314	2,358	1,830
1930	3,349	17,868	1,656	10,189
1931	2,830	14,834	1,545	15,227
1932	2,457	13,418	1,136	12,455
1933	2,273	11,227	919	14,116
1934	3,603	12,556	1,139	16,864
1935	4,603	13,755	1,560	20,483
1936	5,868	14,582	1,650	27,223

TABLE IV

Value of Crude Petroleum and Number of Producing Wells, Rocky Mountain States, 1934-1935*

	Montana	Wyoming	Colorado	New Mexico
Number of producing wells				
1934	1,400	3,410	190	640
1935	1,650	3,380	200	840
1936	1,470	3,420	210	1,250
Average production per well per day				
1934	7.0	10.1	16.4	78.3
1935	8.3	11.1	21.9	75.8
1936	10.3	11.7	22.0	71.2
Value at wells, total				
1934	$4,380,000	$10,550,000	$1,060,000	$12,700,000
1935	6,150,000	11,730,000	1,420,000	16,060,000
1936	7,700,000	13,700,000	1,660,000	22,930,000
Value at wells, Average per barrel				
1934	$1.22	$0.84	$0.93	$0.75
1935	1.34	0.85	0.91	0.78
1936	1.31	0.94	1.01	0.84

*Statistics by U. S. Bureau of Mines.

RESERVES AND PROSPECTS

The visible oil reserve in present-known fields in the Rocky Mountain region cannot be itemized with any degree of precision. In the older, fully developed fields, the probable future recovery can be estimated with reasonable accuracy, but in some areas known to be productive, only one or a few wells have been drilled and the limits of production, number of productive zones and possible ultimate recoveries are merely matters of conjecture. Even in areas that are well advanced in development, such as the Lea County fields in New Mexico, authorities may differ widely in their reserve estimates. This is well exemplified by the figures in the accompanying table which are the most recent authoritative estimates of visible reserves in the Rocky Mountain states.

TABLE V

Estimates of Visible Petroleum Reserves in Rocky Mountain States

	Cole Committee Report U.S.G.S. Dec. 31, 1933 Barrels	American Petroleum Institute January 1, 1935 Original Estimate, Barrels	Revised Estimate, Barrels	January1,1937 Barrels
Montana	57,000,000	60,000,000	102,000,000	92,000,000
Wyoming	245,000,000	250,000,000	267,000,000	239,000,000
Colorado	8,500,000	12,000,000	16,000,000	15,000,000
N. Mexico	92,500,000	350,000,000	451,000,000	471,000,000
Totals	403,000,000	672,000,000	836,000,000	817,000,000

Inspection of the above table will show that most of the variations in estimates are in the figures assigned to New Mexico. Recent developments in Lea County, New Mexico, have disclosed reserves that could not have been foreseen a few years ago; and even today, their full significance in the future reserve picture cannot be forecast.

The present reserve estimates of visible supplies in present-known fields should not be regarded as in any sense a measure of the volume of oil that may ultimately be produced. In conjecturing on the possible areas within which new fields may be found, geologists have, at various times, roughly classified lands in several categories of varying degrees of promise. Page 46 reproduces a portion of a map prepared in 1934 by members of the staff of the U.S. Geological Survey, showing the Rocky Mountain region and areas within it classified as either impossible, improbable, unfavorable or possible for oil discovery. The basis of classification is the knowledge that commercial oil supplies are confined to relatively undisturbed sedimentary formations of certain geologic ages, that lie within reach of the drill. It will be observed that a large part of the area of Montana, Wyoming, Colorado and New Mexico is regarded as possible oil-producing

REFINING

The oil refining industry of the Rocky Mountain region has been developed primarily to meet local needs. Most of the refiners, unable to compete in distant markets because of high transportation cost, limit their output to the market requirements of the locality in which they are situated, or to that part of the local market which they are able to control in competition with other refiners. Because of the local character of the industry, the refineries are, for the most part, plants of small capacity: in many cases, mere skimming plants capable of handling but a few hundred barrels per day. Only in a few cases are the plants classed as complete refineries in the sense that they are equipped to manufacture the full range of products possible to produce from the crude used.

The Rocky Mountain refining industry represents but an insignificant part of the refining capacity of the country as a whole.

Petroleum Refineries of the Rocky Mountain Region†

MONTANA

Company	Location	Straight Capacity Bbl/day	Distillation Type	Capacity Bbl/day	Cracking Type
*Aro Oil & Refining Co.	W. Lewistown	1,500	Skimming	800	Dubbs.
B. & M. Refining Co.	Roundup	300	"	.....	.....
Bear Den Refinery	Bear Den	25	"	.....	.....
Big Horn Oil & Refinery Co.	Billings	1,000	"	.....	.....
Big West Oil Co.	Kevin	800	"	500	Dubbs.
*Conrad Refining Co.	Conrad	1,000	"	.....	.....
*Consumers Refining Co.	Collins	500	"	.....	.....
Continental Oil Co.	Lewistown	1,500	"	.....	.....
*Cut Bank Refining Co.	Cut Bank	250	"	.....	.....
Deloraine Refining Co.	Oilmont	250	"	.....	.....
Dunlap Refinery	Cat Creek	75	Topping	.....	.....
Hart Refineries	Hedgesville	100	Skimming	.....	.....
" "	Missoula	300	"	.....	.....
*Ted Hawley	Gallup City	50	"	.....	.....
*Hole Brothers	Cut Bank	250	Topping	.....	.....
*Home Oil & Refining Co.	Great Falls	1,000	Skimming	.....	.....
Eugene Hunt	Winnett	200	"	.....	.....
Independent Refining Co.	Laurel	5,000	"	1,500	Donnelly
International Refining Co.	Sunburst	3,000	"	2,000	de Florez
*Lewis Refineries	Valentine	50	"	.....	.....
C. A. McKeehan	Molt	5	"	.....	.....
Minnesota-Flatwillow Petroleum Co.	Cat Creek	8	"	.....	.....
North West Refining Co.	Cut Bank	2,500	"	1,000	Dubbs.
Red Lodge Refinery	Red Lodge	70	"	.....	.....
*Regal Products Co.	Soap Creek Field	50	"	.....	.....
Russell Oil Co.	Billings	1,000	"	.....	.....
" " "	Butte	500	"	.....	.....
*Snow Cap Oil Co.	Sunburst	330	"	200	Own
*Sunburst Oil & Refining Co.	Great Falls	3,000	"	.....	.....
Unity Petroleum Corp.	Kalispell	800	"	800	Vapor phase
Yale Oil Corp. of S. D.	Billings	2,000	Skimming and Asphalt	.....	.....
" " " "	Miles City	500	Skimming	.....	.....
Total For Montana		27,913		6,800	

WYOMING

*Beck Refinery	Cody	500	Asphalt	.....	.....
*C. F. Bock & Son	Clay Spur	92	Skimming	.....	.....
*California Petroleum Corp. (Utah)	Calpet	300	"	.....	.....
C. & H. Refinery	Lusk	75	"	.....	.....
Capitol Oil & Refining Co.	Cheyenne	250	"	.....	.....
Consumers Oil & Refining Co.	Newcastle	100	"	.....	.....
Continental Oil Co.	Glenrock	2,500	"	1,800	Cross.
Crane Refinery	Moorcroft	50	"	.....	.....
Crook County Refinery	Sundance	50	"	.....	.....
Eclipse Oil & Refinery Co.	Newcastle	270	"	.....	.....
Elk Horn Gas Refinery	Osage	50	"	.....	.....
Fern Oil Co.	Thermopolis	500	Skimming and Asphalt	.....	.....
Gillette Refining Co.	Gillette	150	Skimming	.....	.....
*Golden Eagle Refining Co.	Casper	200	"	.....	.....
*Goshen Oil & Refining Co.	Torrington	250	"	.....	.....
Gray Refining Co.	Newcastle	90	"	.....	.....
Groner Refinery	Sheridan	50	"	.....	.....
*Huber Refinery	Casper	200	"	.....	.....
" "	Riverton	50	"	.....	.....
*Mountain Refining Co.	Kemmerer	500	"	.....	.....
*Northwestern Petroleum Co.	Osage	300	"	.....	.....
Creana Refining Co.	La Barge	100	"	.....	.....
*Osage Refining Co.	Osage	700	"	750	Cross
Pedro Refinery	Newcastle	150	"	.....	.....
*Pilot Butte Refining Co.	Morton	35	Topping	.....	.....
Jack Ralston	Upton	25	Skimming	.....	.....
Red Butte Refinery	Red Butte	60	"	.....	.....
Resolute Oil Corp.	Badger Basin	400	"	.....	.....
*Salt Creek Refining Co.	Columbine	100	"	.....	.....
Sheridan Refining Co.	Sheridan	300	"	.....	.....
C. J. Siggins	Cody	22	"	.....	.....
Silvertop Refinery	Hawk Springs	50	"	.....	.....
Sinclair Refining Co.	Perco	8,000	Skimmingand Lube	4,000	Dubbs and Own
Standard Oil Co. (Ind.)	Casper	12,600	Complete	6,500	Vapor phase
" " "	Greybull	5,000	Skimming and Asphalt	2,500	Cross
*Star Refinery	Osage	130	Skimming	.....	.....
The Texas Co.	Casper	7,000	"	5,000	Holmes-Manley
" " "	"	.....	.....	1,800	Own
" " "	Cody	3,000	Skimming	1,500*	Holmes-Manley
Upton Refinery	Upton	50	"	.....	.....
*Wheatland Refining Co.	Wheatland	50	"	.....	.....
White Eagle Refining Co.	Casper	5,000	"	2,500	Own
*Williams Refinery	San Pedro	50	Lube	.....	.....
Wyoco Refinery	Powell	40	Skimming	.....	.....
*Wyoil Refining Co.	Mills	150	"	.....	.....
Wyoming Gas and Oil Co.	Osage	150	"	.....	.....
Yale Oil Corp.	Worland	500	"	.....	.....
Total for Wyoming		50,189		26,400	

UTAH

*Diamond Oil Co.	Virgin	200	Skimming	.....	.....
Intermountain Refining Co.	Ogden	200	"	.....	.....
*Carl Sealander	"	1,000	"	1,000	Own
Utah Oil Refining Co.	Salt Lake City	6,000	Complete	6,400	Holmes-Manley
*Utah Parks Petroleum Co.	Virgin	100	Skimming	.....	.....
Wasatch Oil Refining Co.	Woods Cross	1,500	"	1,000	Foster-Wheeler
" " " "	" "	.....	.....	1,000	Vapor phase
Total for Utah		9,000		9,400	

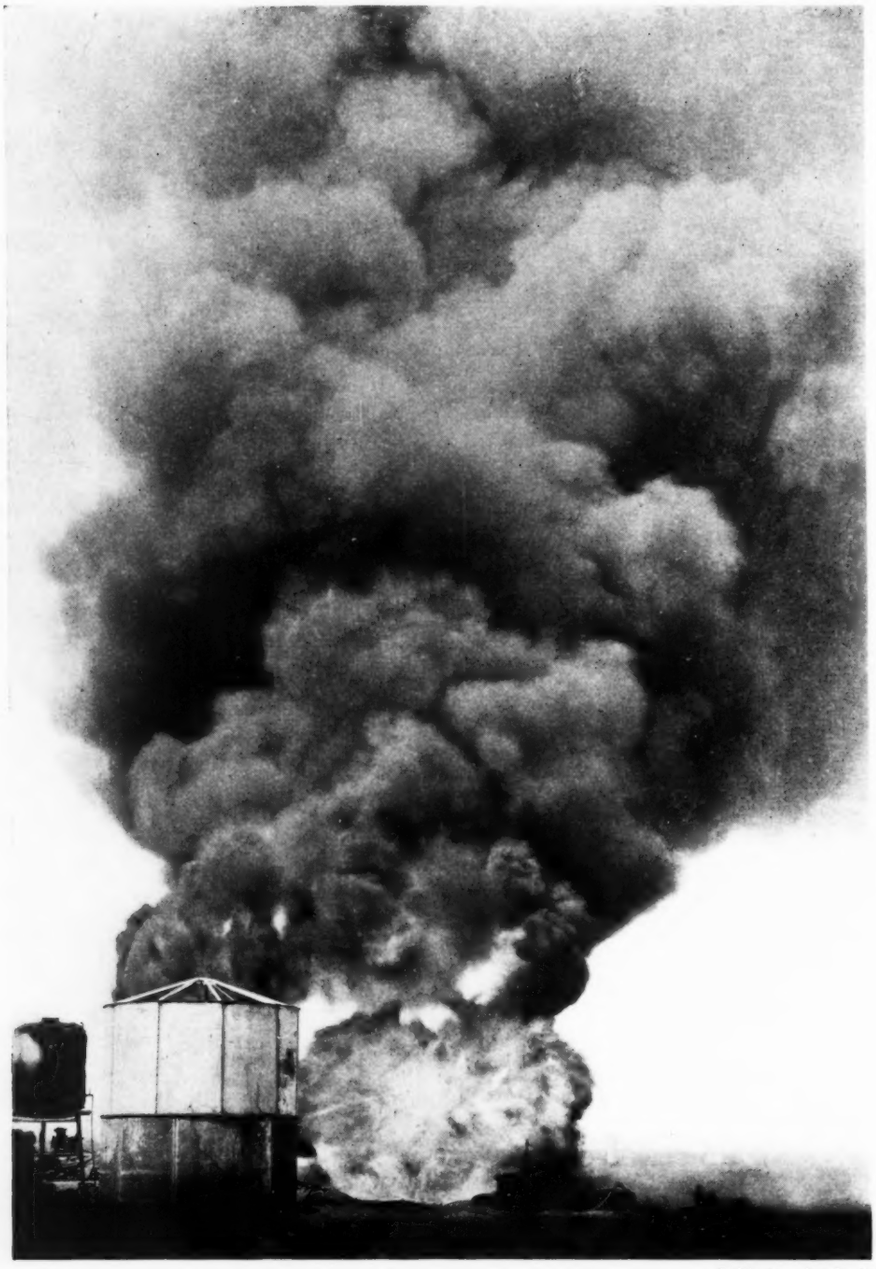
COLORADO

Berthoud Refining Co.	Berthoud	90	Skimming	.....	.....
*Colorado-Midland Refineries, Inc.	Denver	1,800	Asphalt	.....	.....
ContinentalOil Co.	Denver	1,500	Skimming	1,000	Cross
" " "	Florence	3,000	"	850	Burton
" " "	"	.....	.....	450*	"
Fleming Oil, Gas & Refining Co.	Boulder	100	Topping	.....	.....
*Ketner Refinery	Mancos Creek	60	Skimming	.....	.....
McGarr Petroleum Corp.	Marvel	180	"	.....	.....
Raven Oil & Refining Co.	Rangely	200	"	.....	.....
The Texas Co.	Craig	1,000	"	1,000	Holmes-Manley
Total for Colorado		7,930		3,300	

NEW MEXICO

The Aerex Co.	Bloomfield	100	Skimming	.....	.....
Basin Refining Co.	Aztec	100	"	.....	.....
Continental Oil Co.	Albuquerque	1,000	"	.....	.....
" " "	Artesia	1,500	"	.....	.....
" " "	Farmington	1,000	"	.....	.....
Malco Refineries, Inc.	Artesia	2,000	"	.....	.....
McNutt Oil & Refinery Co.	Brickland	1,000	"	500	Donnelly
Pecos Diamond Refining Co.	Artesia	300	"	.....	.....
Valley Refining Co.	Roswell	300	"	.....	.....
Walker Oil Corp.	Hobbs	100	"	.....	.....
Total for New Mexico		7,400		500	
Totals for all Rocky Mountain States		102,432 bbl/day		46,400 bbl/day	

*Idle in 1935 †Statistics by U. S. Bureau of Mines for January 1 ,1935.



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A burning well in the Hobbs Field, Lea County, New Mexico.

Of a total of 471 operating refineries in the United States, 67 are situated in the region, and their gross daily crude capacity is but 2.3 percent of the country's total. Many of the refineries of the region are equipped with cracking facilities, the gross cracking capacity being 49,700-bbl., or 2.3 percent of the country's total cracking capacity. The accompanying table, which presents the most recent statistics assembled by the U. S. Bureau of Mines on the refineries of this region, shows the location of the plants, their crude and cracking capacities, and their classification as to type. It will be noted that Wyoming leads all of the other states of the region in refining capacity and number of refineries, with Montana a poor second in so far as capacity is concerned. New Mexico, Utah and Colorado have comparatively small refining capacities and comparatively few plants. The regional map reproduced on page 51, shows by a special conventional symbol, the locations of all of the refineries listed. Casper, Wyoming, is the most important refining center of the region, three large refineries being situated here, with a gross daily capacity of 25,600 bbl. Casper also has the largest individual refinery of the region: that of the Standard Oil Company on Indiana; crude capacity 12,600 bbl. cracking capacity 6,500 bbl. Other important refining centers are at Shelby, Montana, Parco, Wyoming, Denver, Colorado, and Salt Lake City, Utah. The oil produced in south-eastern New Mexico is shipped out of the district to Gulf Coast refineries. However, a part of the Eddy County production, aggregating about 4,000 bbl. daily, is refined in three plants at Artesia, New Mexico.

Inspection of the refinery table will show that the bulk of the refining business of the region is in the hands of a few of the larger companies, and that refineries owned by purely local concerns are mostly comparatively small and unimportant. The Standard Oil Company of Indiana, with its operations concentrated near Casper, Wyoming, has the largest daily crude capacity among the companies operating in this region, while The Texas Company, with scattered operations at Casper, Cody and Calpet, Wyoming, Sunburst, Montana, and Craig, Colorado, is a close second. The Continental Oil Company has more refineries in the region than any other, with six plants, located at Lewiston, Montana, Denver, Colorado, Albuquerque, Artesia and Farmington, New Mexico, and Glenrock, Wyoming. Other major companies operating refineries in the district, are the Socony-Vacuum Oil Company, Casper, Wyoming, and the Sinclair Refining Company, Parco, Wyoming. More than 57 percent of the crude refining capacity of all of the Rocky Mountain states is owned by the five major companies mentioned, and their influence doubtless extends to other smaller companies not directly connected with them by name.

Technologically, the refineries of the Rocky Mountain region compare favorably in their equipment and methods, with those of other regions. Many of the plants have modern cracking equipment and manufacture products which, from a specifications and performance stand-point, are the equal of products manufactured in the larger refineries of the Mid-continent, Gulf Coast and California districts. All of the better known cracking processes are represented. There is at present, a notable trend toward modernization and expansion of the older plants, extensive replacements and additions to existing refining facilities having recently been made in the refineries at Casper and Parco, Wyoming.

By normal distillation, the lighter grades of green paraffin crudes produced in this region, yield large percentages of gasoline and motor fuel and present no unusual problems in refining. They also yield fair amounts of kerosene and light lubricating stocks, with a small residue that is utilized as fuel or cracking stock in the production

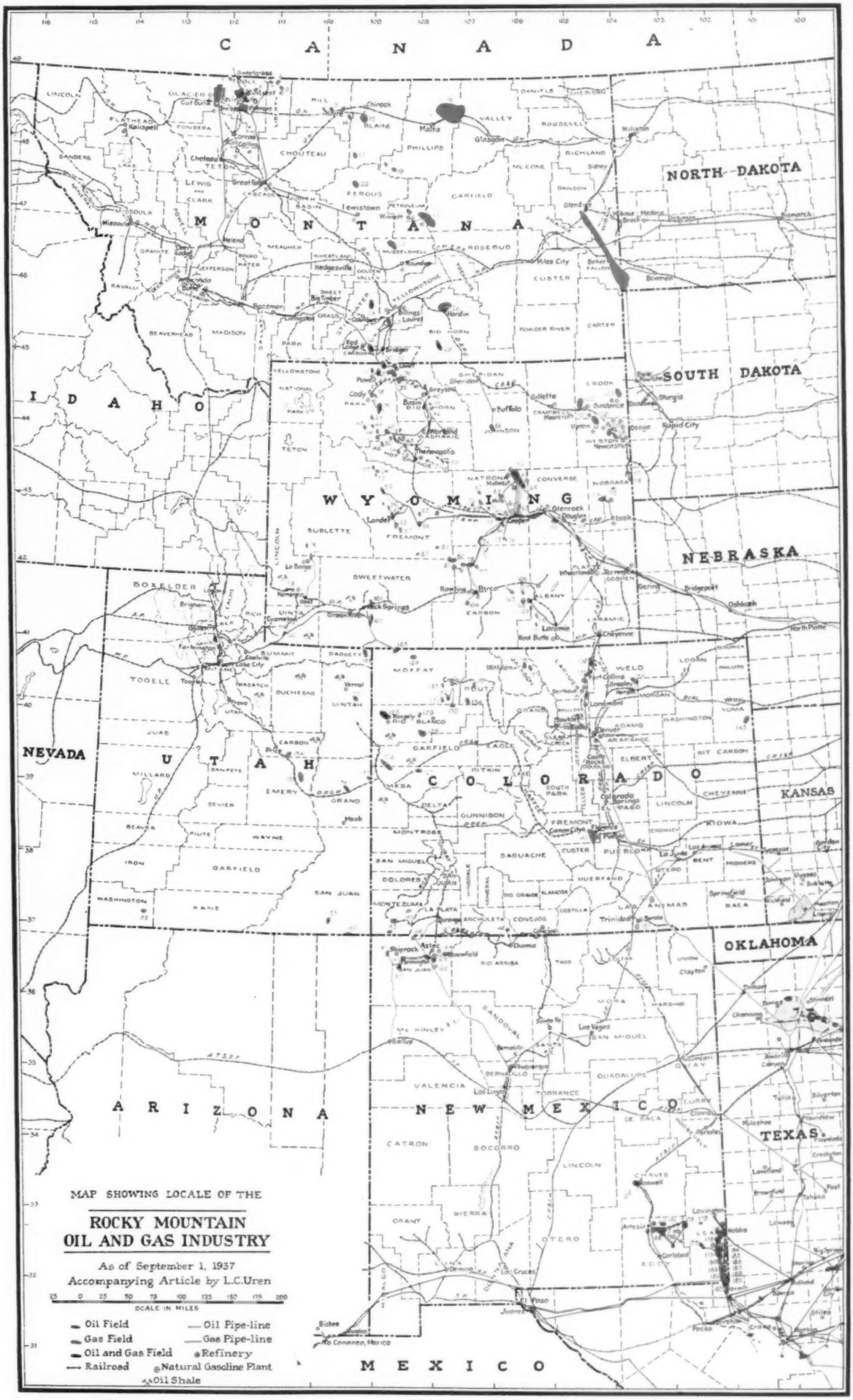


Figure 1 — The extent of the Rocky Mountain petroleum producing area is clearly shown in this map.

of additional motor fuel, with a by-product yield of coke. Refiners have drawn their supplies of the more desirable green oils primarily from the Salt Creek, Lance Creek, Rock River, Lost Soldier, Medicine Bow, Grass Creek, Osage and Big Muddy fields in Wyoming, and the Kevin-Sunburst, Cut Bank and Dry Creek fields of Montana. The so-called black oils, of hybrid or intermediate base, on the other hand, are difficult to refine because of their generally high sulphur content. Of lower A.P.I. gravity, they yield comparatively small percentages of gasoline and motor fuel by straight distillation, and smaller fractions of kerosene, paraffin wax, lubricants and fuel oil. Because of the low yield of desirable products and the difficulty and expense of desulphurizing, the black oils are in little demand among refiners and command a lower price than the lighter green oils. Most of the residuum, after removal of the lighter distillates is utilized as road oil and fuel oil and in the production of asphalt. Many of the Rocky Mountain fields have developed reserves of black oil, notably those of the Big Horn Basin in Wyoming. There are also fields, such as Salt Creek, which have been and are important producers of green oil, but also have reserves of black oil in formations not yet exploited.

Studies of the black oils of Wyoming by U.S. Bureau of Mines technologists, have shown that they range from 30 to 40 deg. in A.P.I. gravity, have carbon residues of from 2.6 to 13.3 percent, asphalt content of from 6.5 to 33.5 percent and sulphur content from 1.5 to 3.9 percent. Motor fuel, cracked gasoline, kerosene distillate, gas oil, lubricating stock, road oil and fuel oil are obtainable from them. The gasoline and naphtha fractions obtained by straight distillation are deficient in light ends and have a sulphur content in excess of that permitted by usual specifications. Light distillates or condensates, such as natural gasoline, must be blended with them to off-set this deficiency and desulphurization is necessary. The quality and yield of motor fuels obtainable from the black oils is improved by cracking, but cracking is difficult and expensive because of their high sulphur and carbon residue content. Some of the black oils yield large lubricating oil fractions, but again, expensive treatment of the lubricating oils produced is necessary because of the high sulphur and carbon residue content. In the past, the volume of black oil refined, in comparison with that of green oil, has been small; but as the supply of the latter diminishes, refiners must place increasing dependence on the black oils. A large reserve of black oil is now shut in and is ready when this need develops. Meanwhile, practical and economical means must be found for refining it. Hydrogenation offers one solution of the problem, though probably not economic at present. Blends of black oil and coal are responsive to hydrogenation and substantial recoveries of gasoline and other products are possible by this means.

TABLE VI

Refinery Operations in Rocky Mountain District, 1932-1935*

	Thousands of Barrels			
INPUT:	**1935**	**1934**	**1933**	**1932**
Runs to Stills	19,282	16,102	14,427	13,934
Natural Gasoline	860	803	819	991
Total Input	20,142	16,905	15,246	14,925
OUTPUT:				
Gasoline	10,705	8,908	8,074	7,993
Kerosene	654	516	570	506
Gas Oil, etc.	1,249	935	776	650
Residual Fuel Oil	3,900	3,485	2,858	2,760
Lubricants	273	231	172	178
Wax, M, Pounds	22,400	15,680	7,000	9,800
Coke, tons	93,400	59,200	67,000	89,500
Asphalt, tons	62,400	32,800	3,400	3,900
Road Oil	816	950	619	826
Still Gas (Oil Equiv.)	1,133	887	834	681
Miscellaneous	51	11	20	2
Shortage	471	470	508	303
Unfinished Oil	....	....	....	514

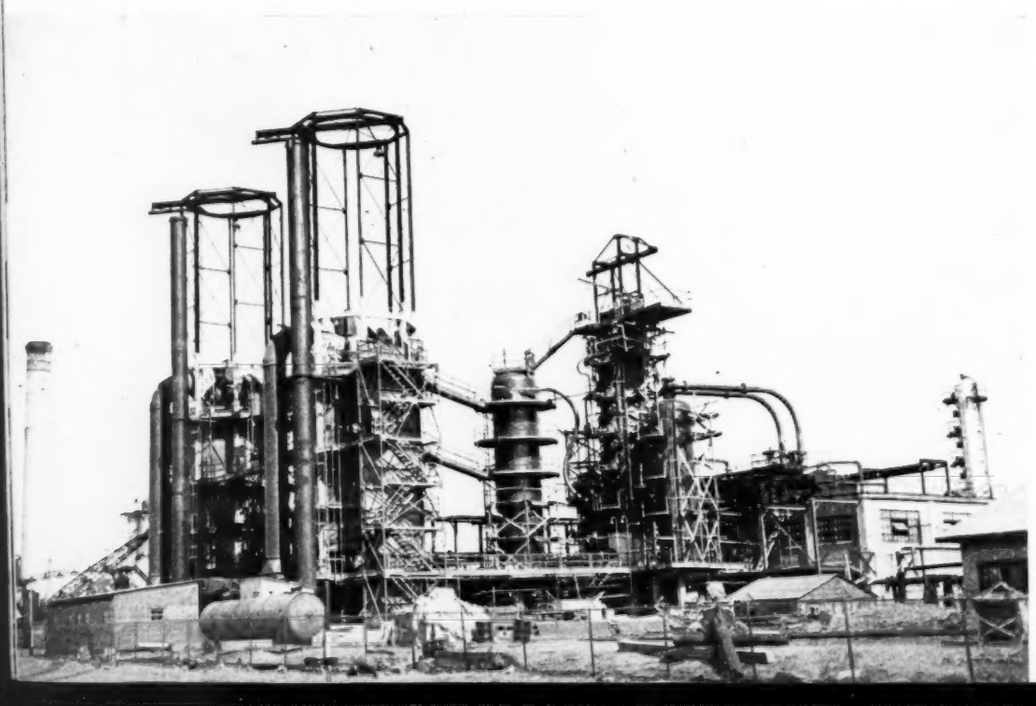
*Statistics by U. S. Bureau of Mines.

Refineries of the Rocky Mountain region rank high among American refineries in the percentage of crude marketed as gasoline, upwards of 50 percent of the crude run to stills being produced as motor fuel. Road oils and coke are also important products from the standpoint of percentage of crude run. A "balance sheet" showing the volumes of crude run to stills and products manufactured in Rocky Mountain refineries during the years 1932 to 1935 inclusive is reproduced in Table VI.

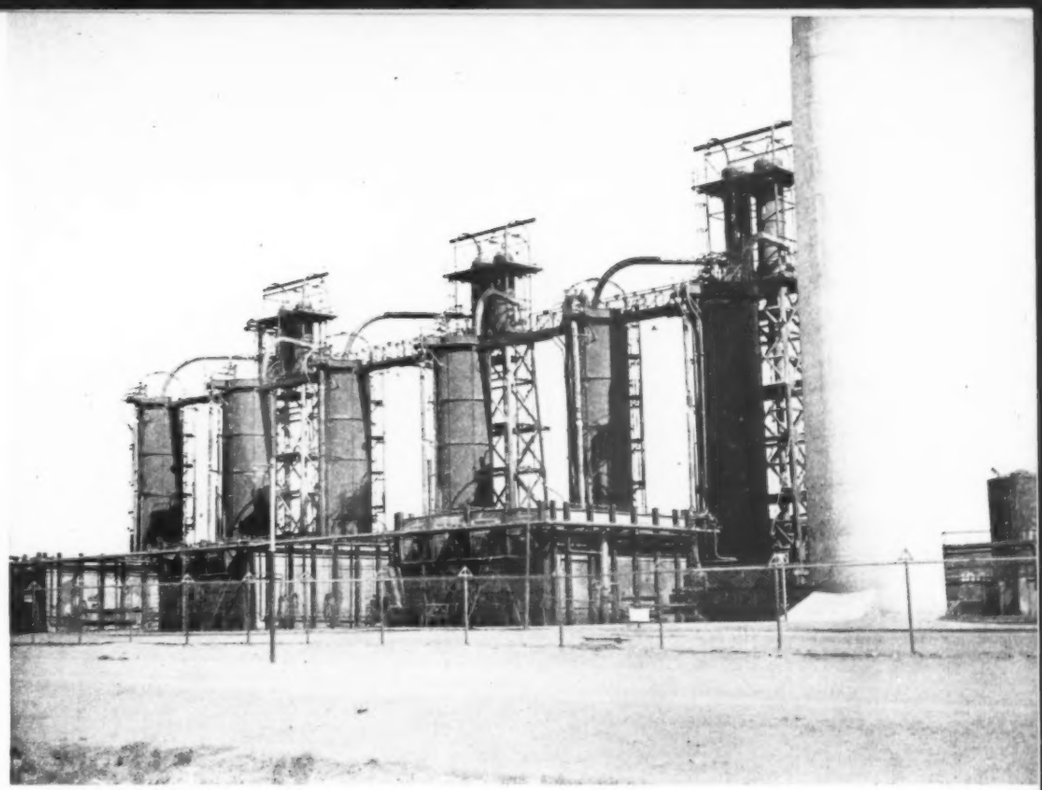
NATURAL GAS

Production and distribution of natural gas is an industry of considerable magnitude throughout the Rocky Mountain Region and important undeveloped gas reserves suggest possibilities for more extensive future expansion of this industry. Many of the more important towns and cities of the region are now supplied with natural gas for domestic and industrial fuel and power development purposes and industries of other kinds, based on this resource, are taking form. The foregoing review of producing fields indicates that there are many areas throughout the region where gas is available in sufficient quantity to justify commercial exploitation, but in many cases development has lagged because of absence of a market for the gas within an economic transmission radius. In spite of a great shut-in reserve of gas in the region, a considerable amount of that distributed by utility companies in Colorado and New Mexico towns and cities is brought in pipelines connecting with fields in Texas and Kansas. On the other hand, some gas is shipped out of the region from fields in Montana to the adjoining states of North and South Dakota and some of the gas produced in south-eastern New Mexico is transmitted to industrial markets and population centers in western Texas and southern Arizona. Utah, without developed gas reserves of her own, is served by a pipeline system extending from Wyoming. While there is thus some interstate movement of gas, both within and without the Rocky Mountain region, the gas produced is, for the most part, consumed near its point of origin.

Natural gas production statistics for the several Rocky Mountain states are given in the accompanying tables. The map reproduced on page 51 shows, by means of color conventions, the gas-producing fields of the region and the gas pipelines connecting the fields with the various towns and cities served. It will be noted that many of the fields are, as yet, without pipeline outlets. Though the region has large reserves, the present rate of gas production is but four percent of the annual gas production of the United States. Of the several producing states in the region, New Mex-



New cracking facilities under construction, Sinclair refinery, Parco, Wyoming.



Cracking Plant, Sinclair refinery, Parco, Wyoming.

ico leads Wyoming by a narrow margin in current rate of production, Montana ranking third and Colorado fourth. Utah's production is negligible. Only within recent years has New Mexico assumed leadership in gas production, Wyoming formerly having a production rate about twice what it is today. From the standpoint of gross past production, Wyoming exceeds that of all other Rocky Mountain states combined.

The natural gas industry of Montana had its beginning with development of the Cedar Creek (Baker-Glendive) anticline in 1915. However, early development of the industry was slow and intended only to satisfy local needs. Since 1926, more extensive pipeline systems have been constructed, until today this field is the focal point of lines extending out in four directions and aggregating many hundreds of miles in length. Producing gas fields, in addition to the Baker-Glendive field already mentioned, now include Dry Creek, Lake Basin, Hardin, Bowdoin, Bowes, Boxelder, Kevin-Sunburst, Whitlash, Border-Red Coulee and Cutbank. Some of these fields also produce oil. Gas has also been found in several other localities, such as Brown's Coulee and Kremlin, Bear's Den and Flat Coulee, Quinn Dome, Cone Butte Dome and Sherard; but these areas have not been developed because of inaccessibility and lack of market. Probably none has very large reserves.

TABLE VII

Natural Gas Statistics, Rocky Mountain States 1924-1935

Natural Gas Produced and Delivered to Consumers 1924-1935

Millions of Cubic Feet

Year	Colorado	Montana	New Mexico	Wyoming	Utah
1924	48	1,071	.....	46,036	.....
1925	574	1,496	.....	45,539	.....
1926	554	2,283	991	46,567	.....
1927	1,725	4,253	1,019	43,582	.....
1928	2,931	6,277	838	47,490	.....
1929	2,787	9,659	3,054	44,648	.....
1930	3,312	10,060	9,497	43,219	.....
1931	2,536	10,949	19,354	39,770	.....
1932	2,547	13,295	17,604	28,938	.....
1933	2,449	14,391	19,148	25,830	.....
1934	2,633	14,971	24,075	23,148	182
1935	2,843	19,870	27,931	26,643	244

*From U.S. Commerce Department "Minerals Yearbook" and supplements.

The Baker-Glendive field is the largest yet discovered from the standpoint of available reserves. Pipelines carrying gas from this field extend to Miles City, Terry and Glendive in Montana; to Williston, Bismarck and Mandan in North Dakota, and to Lead, Deadwood, Belle Fourche and Rapid City in South Dakota. The Dry Creek field in Carbon County, Montana, which was discovered as recently as 1930, supplies several important cities in Montana, including Livingston, Red Lodge, Big Timber, Billings and Bozeman. The Lake Basin field, a small pool in Stillwater County, for a time supplied gas to a carbon black plant. However, this plant has been idle since 1931. The Hardin Field in Big Horn County, also small, supplies gas to the town of Hardin. The Bowdoin Field in Phillips County, supplies the towns of Malta and Glasgow; and the Bowes Field in Blaine County, furnishes gas to Havre and Chinook. A pipeline also extends from Havre to the Boxelder Field in Hill County. The Kevin-Sunburst Field, Toole County, supplies gas to the cities of Shelby, Great Falls, Conrad and Choteau. The Cut Bank Field in Glacier County, which has developed important gas reserves, is connected by pipeline with Butte and Anaconda, important mining and metallurgical and population centers, and with Helena, the state capital.

Natural gas was first utilized commercially in Wyoming in 1909, when the towns of Basin and Greybull were connected by pipeline with small local supplies that have long since been depleted. In 1911, a pipeline was constructed to carry gas from the Garland Field in Big Horn County, to the town of Byron. Later, this line was extended and others constructed, connecting the more important and accessible gas fields of the Big Horn Basin with Thermopolis Basin, Greybull, Garland and Cody, Wyoming; and extending to Billings, Livingston and Bozeman in Montana. A carbon black plant was connected with this system in 1916, but its operation was discontinued a year later, when the Wyoming legislature passed legislation prohibiting use of natural gas for this purpose. The fields commercially exploited for gas production in northern Wyoming include Hidden Dome, Golden Eagle, Garland, Byron, Oregon Basin and Little Buffalo Basin. In 1935, it was estimated that the gas reserves of this district exceeded 500,000,000,000 cu. ft. and that deeper zone exploration might disclose substantial additional reserves.

In central Wyoming, an important group of gas fields, including Wertz, Mahoney, West Ferris and Middle Ferris, supply refineries and domestic markets at Casper, Parco and Rawlins. The gas produced in the Wertz Field is an important source of natural gasoline, but in others of the group, the gas is practically dry.

TABLE VIII

Rocky Mountain States, Natural Gas Statistics 1935

State	Number of Operating Wells	Marketed Production Millions of cu. ft.	Value, Dollars At Wells	Value, Dollars At points of Consumption
Montana	350	19,870	785,000	5,587,000
Wyoming	110	26,643	831,000	4,125,000
Colorado	20	2,843	101,000	646,000
Utah*	30	244	16,000	120,000
New Mexico	30	27,931	508,000	4,292,000
Totals	540	77,531	2,241,000	14,770,000
Total for U.S.	53,790	1,916,595	110,402,000	429,374,000

*Includes Washington and South Dakota.

The South Baxter Basin and North Baxter Basin fields in Sweetwater County, south-western Wyoming, and the Hiawatha and West Hiawatha fields on the Wyoming-Colorado boundary line, are important fields that are connected by a 345-mile pipeline system with towns and cities in south-western Wyoming and north-central Utah. Salt Lake City, Ogden, Tooele, Farmington, Brigham and Logan and the important metallurgical and other industries in this region are supplied from this source. The Clay Basin field in north-eastern Utah is also connected with this

Photo by Roy V. Davis

Smoke from a sump fire frames a vista of the Hobbs Field, New Mexico.

system. Another comparatively short and isolated gas pipeline connects the Allen Lake Field in Carbon County with the city of Laramie, in Albany County; and another isolated system connects the Billy Creek Field in Johnson County with Buffalo and Sheridan.

Commercial production and distribution of gas in Colorado began with the discovery of a large reserve of gas in the Wellington Dome in 1923. A gas line was constructed first to near-by Fort Collins, and in 1926, to Cheyenne, Wyoming. Natural gas has been found in commercial amounts at scattered points in Colorado, notably in the Piceance Creek, Thornburg, White River, Carbonero (or Garmesa), North and South McCallum, Mancos Divide, Wellington, Rangely, Ute Dome, Price, Bell Rock, Garcia, Model Dome and Powder Wash fields. The Hiawatha and West Hiawatha fields on the Colorado-Wyoming border, have already been mentioned in connection with the Wyoming natural gas industry. The Arickaree and Williams Park fields, at one time productive of gas, are now abandoned. Of these, only the Hiawatha and West Hiawatha, the Berthoud and Wellington fields are today of commercial importance, the others mentioned being without commercial outlets.

Only one important pipeline system serves Colorado cities, towns and industries. This extends 340 miles north-westerly from the Panhandle Region of Texas, and serves the communities of Las Animas, La Junta, Rocky Ford, Pueblo, Canon City, Colorado Springs, Denver, Littleton, Golden, Boulder, Longmont, Greeley, and Fort Collins in Colorado, and crosses the Colorado-Wyoming boundary to serve the city of Cheyenne, Wyoming. Lines connecting with a mid-continent gas transmission system cross the Kansas-Colorado boundary from the Hugoton Field in Kansas to reach the towns of Lamar, Holly, Springfield and others in south-eastern Colorado. Another short gas line connects the Ute Dome Field on the Colorado-New Mexico border with the town of Durango in south-western Colorado, supplying important industries in that vicinity. Another short line connects the Craig Dome with the town of Craig in Moffat County.

It will be observed that Colorado, one of the most populous and industrialized states of the Rocky Mountain group, and possessing extensive undeveloped gas reserves, yet is served for the most part, with gas from surrounding states. The reason for this is probably to be found in the comparative inaccessibility of most of the Colorado gas fields, and the previous availability of an extensive reserve of cheap gas in the Texas Panhandle and in south-western Kansas. The undeveloped Colorado fields are thus in the position of seeking market outlets when all of the important markets of the state are adequately supplied from outside sources, through facilities previously provided.

Important gas reserves have been developed in San Juan County, north-western New Mexico, and in Lea and Eddy Counties, in the south-eastern portion of the State. Discoveries were made as early as 1921, but pipelines were not constructed until 1929 and later years. In San Juan County, the South Ute, Rattlesnake, Hogback, Huntington Park, Kutz Canyon and Table Mesa fields are known to contain reserves of natural gas. The Kutz Canyon field is connected by pipeline with near-by Farmington, and by a longer line with the cities of Albuquerque, Santa Fe, Bernalillo, Las Vegas and Los Lunas, all in the northern half of the state.

Large gas reserves have been developed in the fields of Lea and Eddy Counties in south-eastern New Mexico. In eastern Lea County, approximately 250 square miles have been shown productive by scattered wells. Most of the fields that produce oil in the region also contain gas in quantity, not only in direct association with the oil, but also in separate gas pays above the oil-yielding strata. The importance of eastern Lea County as a gas reserve became apparent in 1928. Since that time, many large wells have been drilled in the area. In 1935, it was estimated that 32 wells in the district had a daily capacity in excess of 1,000,000,000 cu. ft., but withdrawals have been but a small fraction of this amount. The Hobbs Field produces upwards of 40,000,000 cu. ft. per day with the oil from the White Lime horizon, but the overlying gas sands are cased off in most of the wells. Gas from this field supplies the towns of Hobbs and Lovington. Gas produced from wells in the Jal area in the extreme south-eastern portion of Lea County is transmitted through a 210-mile, 16-inch pipeline, constructed in 1929 to El Paso, Texas. In 1931, this line was extended to Douglas and Bisbee in Arizona, and to Cananea in northern Mexico, in which districts important mining and metallurgical industries are served with gas. In Eddy County, the Artesia, Vandergriff and Maljamar fields supply gas to the

Workers quarters at the camp in the Hobbs Field, New Mexico

cities of Carlsbad, Artesia, Hagerman and Roswell. In eastern New Mexico, the towns of Clovis, Portales and Tucumcari are supplied with gas from the near-by Amarilla District in the Texas Panhandle.

Such gas as is distributed to consumers in Utah has its origin chiefly in the Hiawatha and Baxter Basin fields of Colorado and Wyoming, as explained in a previous section. The less important Clay Basin Field of north-eastern Utah contributes a limited amount of gas to the same system by which gas is transmitted from these fields to Salt Lake City, Ogden, Provo, Tooele, Farmington, Brigham, Logan and other communities in north-central Utah. This line was constructed in 1929, the first to be provided for commercial distribution of natural gas in Utah. The Farnham and Woodside anticlines in east-central Utah contain important gas reserves, but they have not yet been developed because of lack of markets.

HELIUM AND CARBON DIOXIDE

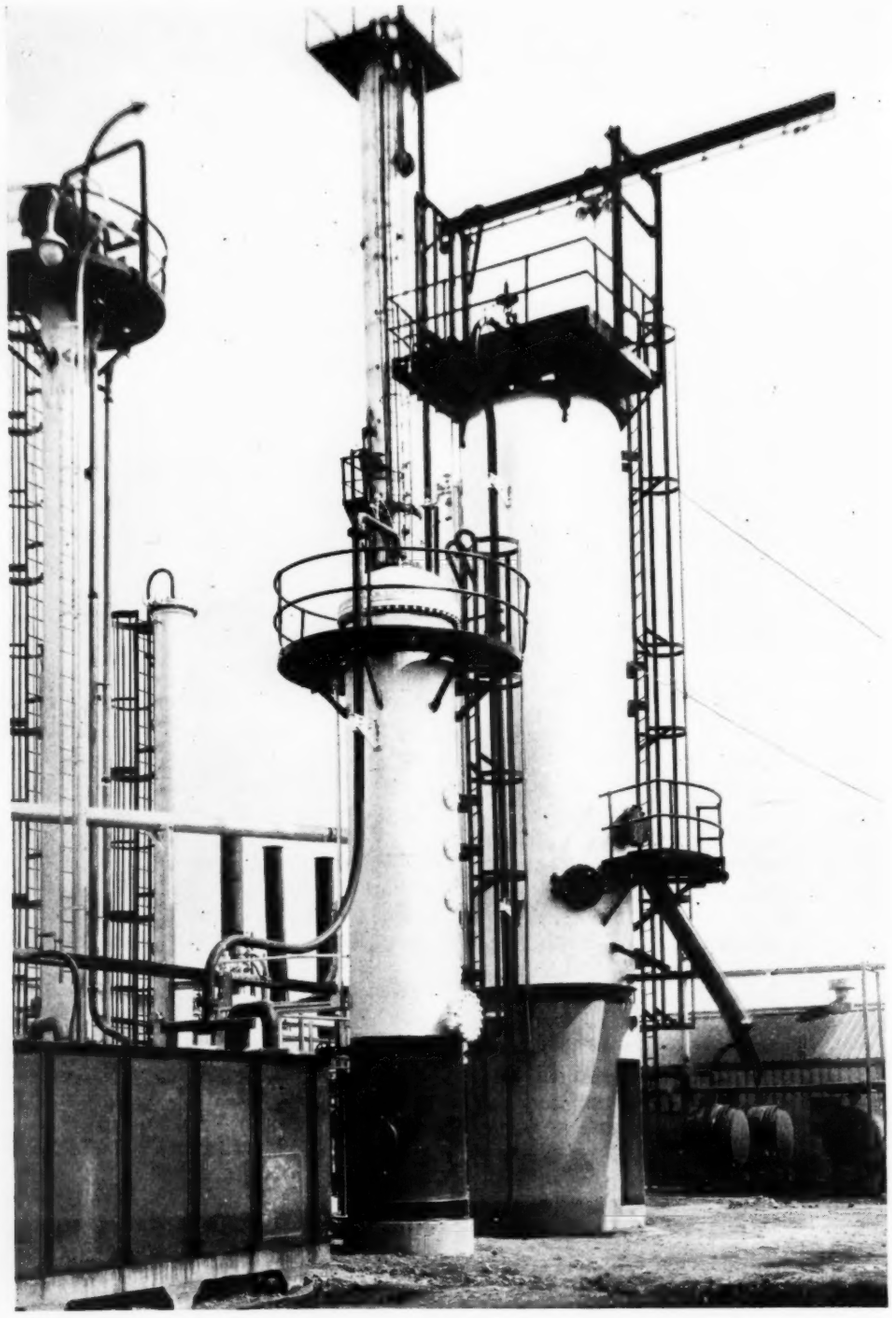
In addition to hydrocarbon gases, to which the above sections relate, two other natural gases are found in important amounts in the Rocky Mountain region. These are helium and carbon dioxide, both of which have possibilities for commercial development.

Helium is a rare gas, useful in floating air craft of the lighter-than-air type, thought to be derived from disintegration of radioactive elements in deep-seated crystalline rocks. It occurs as an impurity in many hydrocarbon gases, but seldom in quantities exceeding one or two percent. Gas produced in the Model Dome field, Las Animas County, Colorado, yields more than seven percent of helium and 81 percent of nitrogen. The Helium Company of Louisville, Kentucky, drilled six wells on this structure and extracted helium from the gas during 1930. The wells had open-flow capacities of from 1,000,000 to 2,000,000 cu. ft. daily. A well in the Woodside field, Emery County, Utah, had an open-flow capacity of 9,000,000 cu. ft. daily, of gas that continued 1.31 percent of helium and 62.33 percent of nitrogen. This field has been set aside by the federal government as a helium reserve. A well on the Harley Dome, Grand County, Utah, had an open-flow capacity of about 2,000,000 cu. ft. of gas daily, containing 7.16 percent of helium. In the Kevin-Sunburst and Pondera fields of Montana, and in the Baxter Basin field of Wyoming, the natural gases produced contain from one-quarter to three-quarters of one percent of helium.

Carbon dioxide is of commercial interest as a source of dry ice. Wells capable of producing large amounts of carbon dioxide under high pressure, have been drilled in the North and South McCallum (Walden) Fields of Colorado. The gas contains about 92 percent of carbon-dioxide and is stored in the formation under a pressure of about 1,000 lb. per square inch. Wells drilled in these fields developed an average initial production of about 35,000,000 cu. ft. per day. The famous ice-cream well, the derrick of which became completely enveloped in dry ice, is situated here. In 1931, the Dry Ice Corporation of America operated an experimental plant using gas from this field, but efforts to find a means of segregating the small amount of oil that is produced with the gas, were unsuccessful. In the Carbonera (or Garmesa) Field, Garfield County, Colorado, the gas produced contains 20 to 61 percent of carbon dioxide. Wells drilled on the Jaritos Dome in Colfax County, New Mexico, produced gas yielding 67 percent of carbon dioxide; and on the Wagonmound Anticline, Mora County, New Mexico, the gas produced contains 90 percent of carbon dioxide. Wells on the Wilcox Dome, Torrance County, New Mexico, and on the Baca structure, Harding County, also yield high percentages. In the Woodside Field, Emery County, Utah, wells produced a gas containing 32 percent of carbon dioxide; and gas produced from the Farnham Dome, Carbon County, Utah, yields as much as 98 percent. The Carbon Dioxide and Chemical Company has a plant in the latter area for commercial production of dry ice. Other areas in Utah are also productive of carbon dioxide, particularly the San Juan Canyon and Cedar Mesa anticlines in southern San Juan County.

NATURAL GASOLINE

The natural gasoline industry of the Rocky Mountain region is of insignificant proportions in comparison with development of the industry elsewhere in the United States. Only 15 plants of a total of 710 in the United States, are situated in this region and their gross capacity is only 286,300 gal. per day, or about 2.7 percent of the country's total. Eight of these plants are in Wyoming, four are in New



New Mexico's refineries are small but modern and efficient: Continental Oil Company's refinery, Artesia.

TABLE X

Natural Gasoline Production Statistics, Rocky Mountain States*

Year	Production, Thousands of Gallons Mont.	Wyo.	Colo.	N. M.	Total
1924	.....	29,272	.....	.....	29,272
1931	.....	51,523	659	17,775	69,957
1932	.....	44,391	472	17,507	62,370
1933	1,295	34,103	408	19,149	54,955
1934	1,237	34,799	643	21,748	58,427

Statistics for 1934

	Mont.	Wyo.	Colo.	N.M.	Total
Number of Operators	1	6	2	3	12
Number of Plants Operating	1	9	3	2	15
Value at Plants, Thousands of Dollars	83	1,598	18	570	2,269
Average, per gal., cents	6.7	4.6	2.8	2.6	....
Natural gas treated, Millions of cubic feet	4,114	17,566	511	11,904	34,095
Average yield per M cu. ft. of gas, gallons	0.30	1.98	1.26	1.83	....

*Statistics by U. S. Bureau of Mines.

Mexico, two in Colorado and one in Montana. New Mexico plants, though fewer in number than those of Wyoming, have the greater gross capacity, New Mexico's daily capacity being 145,000 gal., while that of Wyoming plants is 118,800 gal. The regional map reproduced on page 51 shows the locations of these plants. An accompanying table also gives their locations and particulars concerning ownership, type and capacity and gives natural gasoline production statistics for recent years. Ten of the plants are of the oil absorption type and five are of the compression and refrigeration type.

In view of the volume of gas produced and available, it would appear that the natural gasoline industry is under-developed in this region. However, much of the available gas is shut in and until a market for dry gas is developed, there will be no need for gasoline recovery plants to process it. Much of the gas is so deficient in gasoline-forming components, that gasoline recovery operations would not be profitable. In many fields, the oil is produced with rather low gas oil ratios, so that there is little gas surplus after local lease requirements have been satisfied. In other cases, gas wells are scatterred over wide areas, so that gathering of it in sufficient quantity to operate an extraction plant would be costly.

TABLE IX

Natural Gasoline Plants in the Rocky Mountain Region*

	Type	Daily Capacity, Gallons
Montana		
Glacier Production Co., Butte, Sec. 22-33 N.-5W. Glacier County	Absorption	16,000
Wyoming		
Continental Oil Co., Columbine, Natrona Co.	Compression	4,000
Continental Oil Co., Lance Creek, Niobrara Co.	Absorption	10,000
Ohio Oil Co., Kirby, Hot Springs Co.	Compression	3,600
Ohio Oil Co., Rock River, Carbon County	Absorption	5,000
Sinclair Wyoming Oil Co., Bairoil, NE¼, Sec. 10-26N-90W	Compression	1,200
Sinclair Wyoming Oil Co., Bairoil, NE¼, S.W.¼, Sec. 7-26N-89W	Absorption	5,000
Sinclair Wyoming Oil Co., Columbine, NE¼, NE¼, Sec. 13-39W-79W	Absorption	5,000
Stanolind Oil & Gas Co., Midwest, Natrona Co	Compression	85,000
Total Capacity, Wyoming		118,800
Colorado		
Fort Collins Production Corp. (Continental Oil Co.,) Fort Collins, Larimer County	Compression	500
Mountain States Oil Corp., Barela, S.W.¼, Sec. 3-33S-62W	Absorption	6,000
Total Capacity, Colorado		6,500
New Mexico		
Continental Oil Co., Hobbs, Lea County	Absorption	30,000
Natural Gasoline Corp., Monument, Sec. 36-19S-36E, Lea County	Absorption	50,000
Natural Gasoline Corp., Nonument, Sec. 1-20S-36E, Lea County	Absorption	
Phillips Petroleum Co., Eunice, NE¼, Sec. 5-21-36, Lea County	Absorption	25,000
Phillips Petroleum Co., Hobbs, N½, NW¼, Sec. 4-19-38, Lea County	Absorption	40,000
Total New Mexico		145,000
Total Rocky Mountain Capacity		286,300
Total U. S. Capacity		10,691,352
Total number of plants in Rocky Mountain area		15
Total number of plants in U.S.		710
Utah		
(None)		

*From tabulation in Oil and Gas Journal, May 20, 1937.

OIL TRANSPORTATION

Transportation of crude petroleum and its products in the Rocky Mountain region is dependent upon the railroad more than in any other producing region of the United States. There are few long-distance trunk pipelines in the district, and oil is moved from the fields to the refineries for the most part, by short pipelines to the nearest rail connection, and then by railroad tank car to the refinery, which is situated usually in some near-by marketing center. Refined products are distributed from the refineries to retail distributing outlets and points of consumption, by railroad tank car or by motor truck. The latter method of transport is sometimes also used in moving crude from the field to the refinery, or to rail transport facilities.

A survey of oil pipelines of the United States, published in 1932, credited the several Rocky Mountain states with the following mileages of gathering and trunk lines:

TABLE XI

State	Gathering Lines, Miles	Trunk Lines, Miles
Montana	215	60
Wyoming	690	610
Colorado	90	90
New Mexico	350	150
Total	1,345	840
United States Total	53,640	58,020

It is believed that these figures have not been greatly altered during the last five years. Calculations indicate that the Rocky Mountain region contains only about two percent of the country's gathering lines and 1.5 percent of the country's trunk pipelines. From the standpoint of capacity, the Rocky Mountain pipelines are even less impressive, as most of them are of small diameter.

A study of the distribution of oil pipelines, as disclosed by the map of the Rocky Mountain region on page 51, shows that the only pipeline systems of any magnitude are in Wyoming. The most notable of these, and one that ranks among the longest oil pipelines of the world, is that extending from the Teapot Dome Field in central Wyoming, south-easterly to Freeman, Missouri. Owned originally by the Sinclair interests and now by Stanolind, this is the only pipeline by which oil may be shipped out of the northern portion of the Rocky Mountain region. Another pipeline system of importance in central Wyoming, is that of the Sinclair Oil and Gas Company, connecting the Salt Creek Field with the Sinclair refinery at Parco. Several comparatively short pipelines in north-central Wyoming carry oil from the various fields of the Big Horn Basin to refineries at Thermopolis, Cody, Greybull and Worland. Pipelines also connect the Lance Creek Field with rail facilities at Mannville and with the Stanolind midcontinent line at Fort Laramie, Wyoming.

Fields in south-eastern New Mexico are points of origin for several pipelines that connect with other lines in west Texas, and which permit movement of New Mexico crude to Gulf Coast and Midcontinent refineries. Another isolated pipeline system provides for transportation of crude from Eddy County fields to refineries at Artesia; and in north-western New Mexico, pipelines connect the more important producing fields of the San Juan Basin with a refinery at Farmington and with rail facilities at Gallup.

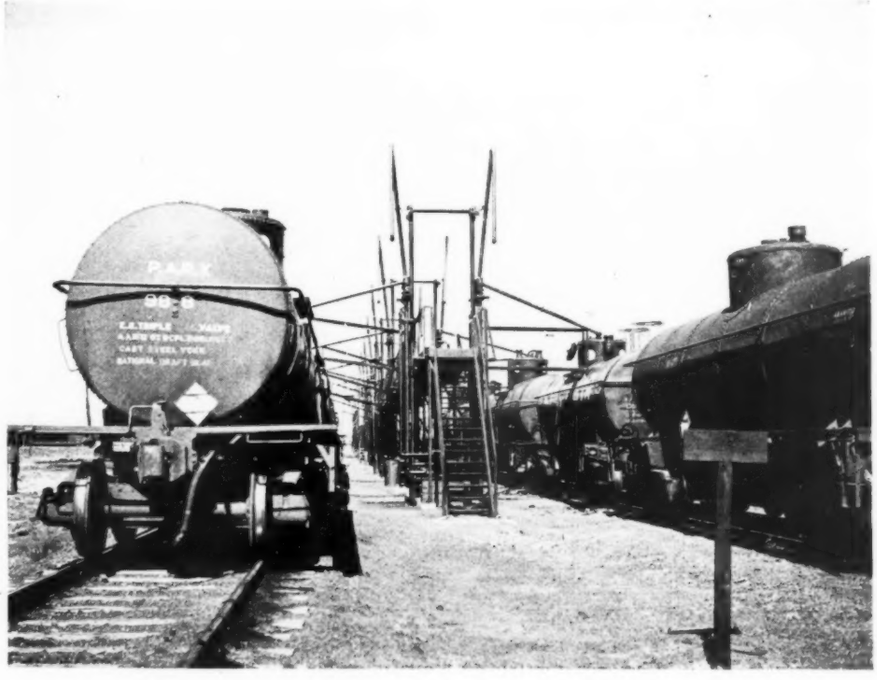
Montana's oil pipelines are for the most part, in or near the Kevin-Sunburst and Cut Bank fields, and are designed for moving crude to refineries or rail connections in the near-by towns of Shelby, Sunburst, Cut Bank and Sweetgrass. Another short line connects the Cat Creek field with refinery and rail facilities at Winnett.

Colorado has only a few short and unimportant oil pipelines. One connects the Greasewood Field with rail facilities at Hardin and two carry oil from the Iles and Moffat fields to a refinery and rail outlet at Craig. Several short lines also focus on the town of Florence from near-by producing areas in the Florence district.

Utah has no oil pipelines.

Only five pipelines for transportation of gasoline have thus far been constructed in the Rocky Mountain region, three in Wyoming and two in Colorado. All are short and used only for movement of gasoline from natural gasoline plants to near-by railroad shipping points. The Stanolind Oil and Gas Company operates a line from its gasoline plant in the Salt Creek field to Casper; and the Ohio Oil Co. operates the other two Wyoming lines, one from the Medicine Bow field to the town of Medicine Bow and the other from Lance Creek to Manville. The two Colorado gasoline lines extend from extraction plants in the vicinity of Fort Collins to rail shipping facilities at that point.

For a sparsely settled region, still underdeveloped industrially, the Rocky Mountain region is well supplied with railroads. There are few communities of any size or of any industrial importance that are far removed from rail facilities. Different portions of the region lie within the sphere of influence of different railroad systems. For example, northern Montana is served exclusively by the Great Northern system; central, southern and western Montana, by the Northern Pacific and Chicago, Milwaukee and St. Paul systems. The Chicago, Burlington and Quincy system serves eastern and central Wyoming and the Union Pacific, southern Wyoming and northern Colorado and Utah. The Denver and Rio Grande Western and Denver and Salt Lake lines monopolize western Colorado and eastern Utah; and the Chicago, Burlington and Quincy, Santa Fe, Chicago and Rock Island, Union Pacific, Missouri Pacific and Colorado and Southern railways share the rail transportation business in central, eastern and southern Colorado. The Santa Fe railroad system has most of the trans-



Tank cars and loading rack—Parco, Wyoming.

Exposure of Green River oil shales near De Beque, Colorado.

Courtesy U. S. Bureau of Mines

portation business in New Mexico, though the Southern Pacific and Chicago, Burlington and Quincy and Colorado and Southern also participate in some sections. The Texas and New Mexico Railroad, a branch of the Texas and Pacific Railroad, serves the Lea County fields in south-eastern New Mexico. The Denver and Rio Grande Western and its affiliate, the Western Pacific, serve Utah and the Union Pacific, south-western Utah. The general map on page 51 shows the routes followed by the principal railroads of the region.

Many tank cars are engaged in carrying crude petroleum to the various refineries of the region and in moving refined products to the distributing centers. A large part of the freight moved by the railroads of the region is crude oil and products derived therefrom. The more important refining centers thus become the points of origin of this rail movement of refined products. In some instances too, where refineries are not served by pipelines connecting with the producing fields, these same refining centers become focal points for rail movement of crude. Important railroad centers for handling oil-industry products are Sunburst, Kevin, Cut Bank, Shelby, Great Falls, Billings and Laurel in Montana; Casper, Glenrock, Manville, Parco, Thermopolis, Greybull and Cody in Wyoming; Denver and Craig in Colorado; Salt Lake City and Ogden in Utah; and Farmington, Gallup, Albuquerque and Artesia in New Mexico.

Motor trucks are playing an increasingly important role in transportation of both crude petroleum and refined products, especially where the haul is comparatively short. Many of the smaller producers and refiners are dependent upon this means of transportation or prefer it to rail transport because of its more direct service, and at times, lower cost. Large numbers of tank trucks are to be observed on the highways, particularly in Wyoming and Montana. Local distribution of refined products from the refineries to distributing points in nearby towns is usually by motor tank truck.

OIL STORAGE

About eight months' supply of crude petroleum is held in above-ground storage in the Rocky Mountain states: a considerably greater supply in terms of current rate of consumption than is maintained in other oil-producing regions of the United States. About nine percent of the United States storage reserve is in this region, though the refinery throughput is only about two percent of the country's total. Nearly 90 percent of this storage reserve is in Wyoming, particularly in the vicinity of Casper, where large tank farms are situated. Of course, every producing field, refinery, pipeline pumping station and rail shipping point must maintain a certain storage reserve which, though individually small, may in the aggregate represent a considerable amount.

Statistical data concerning the storage reserves in the several Rocky Mountain states are given in the accompanying table The second part of this table indicates the amount of oil produced in Rocky Mountain states in storage partly in these states, and also in other states to which shipment has been made.

TABLE XII

Stocks of Crude Petroleum in Storage, Rocky Mountain States, 1933-1937

State	Thousands of Barrels				
	Dec. 31, 1933	Dec. 31, 1934	Dec. 31, 1935	Dec. 31, 1936	March 31, 1937
IN STORAGE IN:					
Montana	623	1,075	1,127	1,028	1,477
Wyoming	26,719	26,733	25,926	24,601	24,294
Colorado	317	439	485	457	401
Utah	270	282	194	113	107
New Mexico	437	536	669	829	902
Totals	28,366	29,065	28,401	27,028	27,181
Total U.S.	354,223	337,254	314,855	288,184	297,496
IN STORAGE IN U.S. AND PRODUCED IN:					
Montana		1,074	1,108	993	1,437
Wyoming		26,909	26,200	25,193	25,123
Colorado		504	403	486	359
New Mexico		4,807	5,533	7,596	8,077

MARKETING

Competition is keen among the refiners and sales organizations of the larger oil companies for market outlets. Some of the companies have extensive chains of service stations for gasoline and motor oil retail sales throughout the region, and these and other petroleum products are conveniently available to large industrial consumers and retail distributers from bulk distributing plants in the larger towns and cities.

About 57.5 percent of the crude run to stills in the Rocky Mountain region, is sold as motor fuel. The accompanying table gives statistics of gasoline consumption during recent years in the five states under review:

TABLE XIIIa

Gasoline Consumption in Rocky Mountain States, 1932-1936*

State	Thousands of gallons consumed during year: 1932	1933	1934	1935	1936
Montana	67,872	69,844	85,484	96,326	108,963
Wyoming	35,364	35,466	43,986	49,498	58,634
Colorado	158,886	159,917	172,756	182,367	205,913
Utah	54,222	54,705	64,140	71,065	81,848
New Mexico	46,746	48,342	56,154	62,340	75,849
Totals	363,090	368,274	422,520	461,596	531,207

*From statistical reports by American Petroleum Institute.

A previous table has shown that Wyoming leads in production of gasoline by a wide margin, but the above table shows that it is the smallest consumer of the Rocky Mountain group of states. It will be observed also, that Colorado leads all other states of the group in gasoline consumption, while Montana is second. Comparison of the motor fuel production and consumption statistics also indicate that in spite of the great oil resources and shut-in reserves of this region, the Rocky Mountain states do not produce enough gasoline to supply their own markets, importing a substantial volume of motor fuel each year from other regions. This is largely due to the sales pressure of marketing organizations deriving their supply of gasoline from California, Mid-Continent and Gulf Coast refineries. Certain marketing organizations, like the Shell Oil Company and the Standard Oil Company of California, for example, have no refineries in the region and yet command a considerable share of the market. Apparently they are able to meet the long-haul freight charges from refineries in other districts and yet compete with the Rocky Mountain refiners on their own terms.

Consumption of gasoline reflects in a general way, the relative populations and industrial development of the several states. The extent to which different districts appeal to motoring tourists doubtless also has a considerable influence on the demand for motor fuel. The consumption of motor fuel varies seasonally, reaching peak values during the summer motoring season when the scenic and climatic attractions of the region lure many tourists. Severe winters, on the other hand, greatly restrict the volume of motor traffic during the colder season of the year. Consumption of gasoline in Colorado, for example, is about 1.5 times as much in June, July and August as it is in December, January and February.

TABLE XIV

Retail Gasoline Service Station Prices, 1935 and 1936

City and State	Tax, Cents Per gallon	Price per gallon without tax* cents July 1, 1937	Jan. 1, 1937	Jan. 1, 1936
Helena, Montana	6	19.5	18.5	17.5
Casper, Wyoming	5	17.0	16.5	15.5
Denver, Colorado	5	16½5	16.0	15.0
Salt Lake City, Utah	5	18.5	18.0	13.0
Albuquerque, New Mexico	6.5	15.0	14.5	15.5

Retail gasoline service-station prices at various times during the last two years, are shown in another table for one of the larger distributing centers in each of the Rocky Mountain states.

TABLE XIIIb

Motor Vehicle Registration, Retail Gasoline Outlets and Dollar Value of Service Station Sales in The Rocky Mountain States, 1935.

State	Population 1930	Population Per Sq.Mi.	Motor Vehicle Registration July, 1935*	Number of Service Stations†	Number of Garages† Selling Gasoline	Dollar-Value of Service-Station Sales†
Montana	537,606	3.6	189,300	927	454	$12,614,000
Wyoming	225,565	2.3.	611,00	499	163	7,069,000
Colorado	1,035,791	10.0	255,900	2,266	769	23,554,000
Utah	507,847	5.9	125,600	887	274	9,736,000
New Mexico	423,317	3.5	79,200	827	202	6,956,000
Totals	2,730,126		651,100	5,406	1,862	$59,929,000

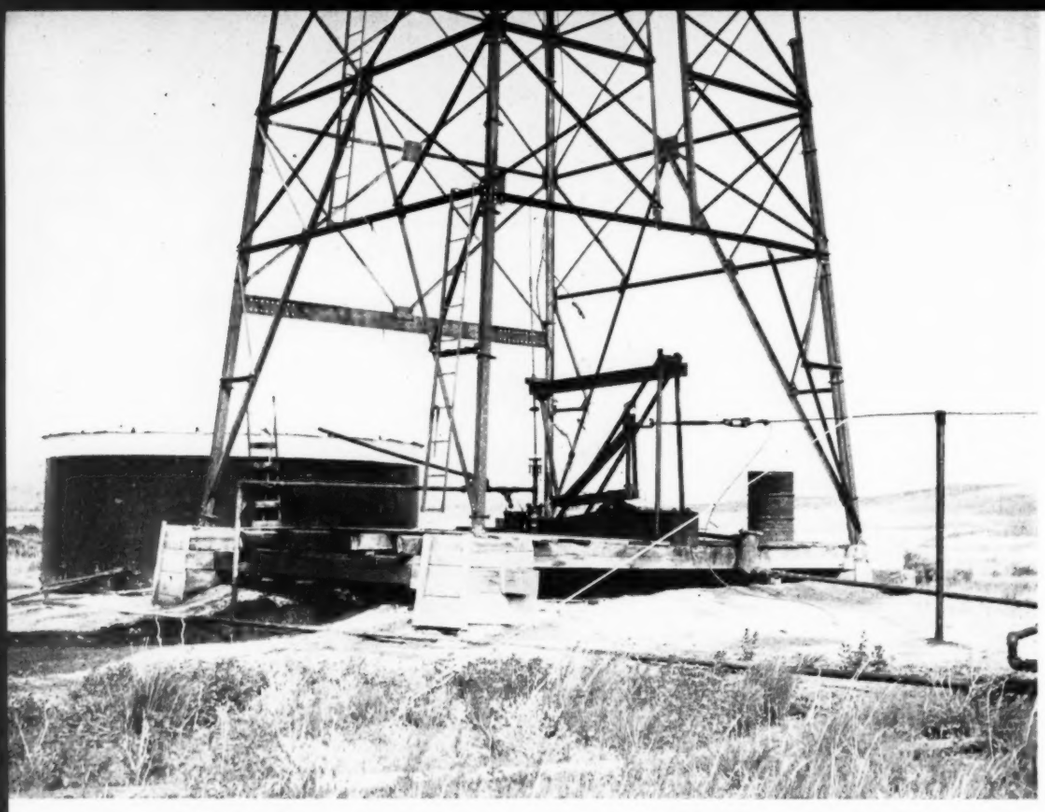
*Motor vehicle registration statistics by American Petroleum Institute.
†Sales statistics by U.S. Bureau of the Census.

In a survey conducted in 1935, the U.S. Bureau of the Census records the number of filling stations and other secondary outlets for marketing gasoline and motor oils in the Rocky Mountain states and the dollar-value of service station sales, as shown in an accompanying table. The number of outlets and volume of business have doubtless increased materially during the last two years. The registration of motor vehicles in this year, as reported by the American Petroleum Institute, is also indicated.

More than one-quarter of the crude run to stills in the Rocky Mountain region is eventually marketed as fuel oil or gas oil. These products find many applications.

Eastern Utah possesses important oil shale resources: shale outcrops near Watson, Utah.

Courtesy U. S. Bureau of Mines



Multiple pumping is common in shallow territory: pumping jack on a well in the Salt Creek Field, Wyoming.

The railroads are the principal consumers, using about 65 percent of the regional supply in 1935, mostly for locomotive fuel. The oil companies themselves are important consumers of fuel oil, about 19 percent of the total supply being consumed in 1935 in developing power and heat in field and refinery operations. An increasing amount of fuel oil is used each year in heating homes, hotels, apartment houses, office buildings, schools and other public buildings. About seven percent of the available supply was used in 1935 for this purpose. Manufacturing industries consumed about three percent in operating power plants and industrial furnaces, and nearly as much was used by utilities in manufacturing gas and in power development. The mining industries of the region are also small consumers.

Two accompanying tables present statistics of fuel and gas oil consumption in the Rocky Mountain region during recent years, and indicate the quantities finding use in different fields of application during the year 1935. Wyoming and Montana are the important fuel-oil consuming states of the group, the railroads and oil industry of these states being important consumers. Less fuel oil is used today than in earlier years. This is due in part to competition with natural gas which, as previously explained, has found wide distribution in the more important industrial and population centers, Also, fuel oil has never found such extensive use in this region as on the Pacific Coast, for example, because of the abundance and cheapness of coal, which is mined commercially in many localities throughout the Rocky Mountain region. Development of cracking facilities in oil refining promises further to reduce the percentage of the crude available for fuel oil. The industrial depression of recent years has had an important influence in limiting the markets for fuel oil. Consumption declined from 1929 until 1932, but since the latter year, has been again increasing.

TABLE XV

Sales of Gas Oil and Fuel Oil, Rocky Mountain Region, 1930-1935*

Thousands of Barrels

State	1930	1931	1932	1933	1934	1935
Montana	1,709	1,002	984	1,098	1,221	1,676
Wyoming	2,010	1,642	1,243	1,234	1,264	1,418
Colorado	389	395	364	371	400	464
Utah	494	269	155	203	254	260
New Mexico	447	223	340	468	753	835
Totals	5,049	3,531	3,086	3,374	3,892	4,653

*Statistics by U.S. Bureau of Mines.

TABLE XVI

Sales of Gas Oil and Fuel Oil in 1935, Rocky Mountain Region*

Thousands of Barrels

Use	Montana	Wyoming	Colorado	Utah	New Mexico	Region Total
Railroads	1,307	936	97	78	597	3,015
Gas and Electric Power Plants	2	8	47	8	58	123
Mines and Smelters	....	....	5	8	5	18
Manufacturing Industries	35	5	50	11	27	128
Heating Oils	71	36	141	25	34	307
Used as Fuel by Oil Cos.	195	416	95	99	97	902
U.S. Navy, Army Transports	25	....	....	....	....	25
Miscellaneous Uses	41	17	29	31	17	135
State Totals	1,676	1,418	464	260	835	4,653

*Statistics by U.S. Bureau of Mines.

If we assume that one ton of asphalt is equivalent to six barrels of oil, it appears that the 62,400 tons of asphalt produced in Rocky Mountain refineries in 1935, represents about 374,400 bbl. of oil. Add to this the 816,000 bbl. of road oil produced and we have a total of 1,290,400 bbl. most of which was utilized in road construction and maintenance: an industry of considerable importance in the Rocky Mountain states during recent years. Until rather recently, most of this region has been difficult of access to automotive traffic, but within the last few years, great progress has been made in bringing the highway systems up to a standard comparable with that of the eastern, middle-western and western sections of the country. Indeed, if one considers the relatively small populations and lack of financial resources of these states for road building, it is apparent that remarkable progress has been made and is being made in developing a system of highways of which even now, the people of this region may well be proud. Recent surveys indicate that Montana has 3,056 miles of bituminous-surfaced highways; Wyoming has 2,425 miles; Utah, 1,360 miles; Colorado, 1,228 miles and New Mexico, 1,150 miles. In most cases, these states have ambitious programmes for further development of their highway systems. Particularly is this true of Montana, which has one of the most progressive and competently administered state highway engineering departments in the United States. Studies and road tests have indicated that properly selected bituminous materials provide an eminently suitable surfacing material for use under the character of traffic and climatic conditions imposed in this region, and it seems likely that it will be even more widely employed in future programmes of highway construction and maintenance than has been the case in earlier years.

OIL SHALE

The Rocky Mountain region possesses important oil-shale resources that may at some future time make it the most important oil-producing region of the United States. Our petroleum resources are not unlimited. The visible reserve of petroleum

in all present-known fields in the United States, producible by present methods, is but 13 years' supply at the present rate of consumption. Doubtless, the visible reserve will be augmented by new discoveries, but eventually discoveries will fall short of consumption and the visible reserve will dwindle, finally compelling restricted production and higher prices for petroleum products. Then it will be necessary to import petroleum from abroad, or develop substitute products. Among the possible substitutes are shale oils derived from so-called oil shale by a process of retorting. Such shales are generally fresh-water sediments containing organic residues called kerogen. They contain little or no oil as such, but on heating to from 650 to 900 deg. F., the kerogen is converted into bitumen which vaporizes, and the vapor may be condensed to form an oil closely resembling crude petroleum. From crude shale oil produced in this way, may be derived motor fuels, lubricating oils, road oils, fuel oils and other products.

Large reserves of oil shale, much of it capable of yielding from 16 to 50 gal. of oil per short ton, are situated in Garfield, Mesa and Rio Blanco Counties of north-western Colorado; in Uinta, Sweetwater and Lincoln Counties of south-western Wyoming; and in Uinta, Duchesne, Carbon and Wasatch Counties of north-eastern Utah. Shales in these areas are a part of the Green River formation of Eocene age. Oil shales are also found in eastern Nevada, near Elko and Carlin; and in western Montana (near Dillon) shales of Permian and Tertiary age yield oil. The Federal Oil Conservation Board reports that oil shales of the United States are estimated to be capable of yielding at least 92,000,000,000 bbl. of oil, or about seven times current visible reserves of petroleum, and the greater part of this huge reserve lies in the Rocky Mountain states.

According to D. E. Winchester, writing in U.S.G.S. Bulletins 641 and 691 in 1916-18, the Green River formation of Utah, Colorado and Wyoming covers a large area and contains beds 500 ft. thick that will yield an average of 15 gal. per ton. Persistent beds ranging up to 49 ft. in thickness yield as much as 35 gal. of crude oil per ton and some portions of the formation yield as much as 60 gal. per ton. In many areas these shales are exposed on mountain slopes so that they may be produced at low cost by surface mining methods. However, these outcrops occur at elevations of from 6,000 to 8,000 ft. and are not easily accessible. The greater part of the shale can be produced only by costly under-ground mining methods.

During the period 1925 to 1927, the U.S. Bureau of Mines operated a pilot shale retorting plant near Rulison, Garfield County, Colorado, which demonstrated that crude shale oil and suitable refined products can readily be produced from the Green River shales. The plant was supplied with shale mined on the U.S. Government Naval Oil Shale Reserve which occupies a large area in this locality. As a result of this and other studies of the shale resources of the region, it has been estimated that crude shale oil can be produced in large-scale mining and retorting projects from shale yielding 35 gal. per ton, for as little as $1.66 per barrel, and one authority estimates that gasoline may be produced from this source for from seven to eight cents per gallon. The better grades of petroleum produced in the Rocky Mountain region today sell for as much as $1.40 per barrel, and one does not have to concede a very great increase in the petroleum industry price structure to visualize the beginnings of a shale-oil industry.

It is interesting to speculate on the industrial and economic readjustments that would have to take place if it were necessary to produce present supply of oil products from oil shale. If the shale mined yields half a barrel per ton, it would be necessary to mine and retort about 7,000,000 tons of shale per day, or about seven times the current production of bituminous coal. The investment in mines and retorting plants would probably exceed $7,000,000,000. A working community of something like 700,000 men would have to be moved in and settled in what is now a barren and sparsely settled region. An entirely new system of pipeline and rail transportation facilities would have to be developed. Such an industry would doubtless require many years for development to a point where oil produced in this way could supplant our present supply of petroleum.

SUMMARY

In the foregoing pages, an effort has been made to appraise the oil and gas industries of an important petroliferous province. All of the oil and gas fields thus far discovered in the Rocky Mountain region have been listed, named and located on a sketch map. The more important fields are described in some detail and the geologic relationships of groups of fields in different districts are discussed. All of the oil refineries of the region are also located on the sketch map and the refining practices as applied to the different types of oil produced, are explained. The pipeline and rail transportation facilities of the region are briefly described and their relationships with the many producing and refining and consuming centers are discussed: again, with reference to the regional map. The marketing phase of the industry is briefly reviewed. The natural gas industry is separately discussed, all of the producing gas fields, gas pipelines, natural gasoline extraction plants and cities served with natural gas being listed and identified with respect to the afore-mentioned map. The potential influence of vast reserves of oil shale as the basis for an important future petroleum-substitute industry in this region is suggested. An effort has also been made to sketch the history and to assemble and interpret the available statistics relative to all phases of the oil and gas industries of the region.

Geologically, the Rocky Mountain province is one of great interest and has been considered with respect to the several structural basins in which the oil and gas fields are found. Producing formations range in age from Carboniferous to Tertiary, much of the oil being found in Jurassic, Permian and Cretaceous strata. Most of the 189 oil and gas fields listed are small and economically unimportant. Comparatively few would be classed among the major oil and gas fields of the country. Of these the Kevin-Sunburst and Cut Bank oil fields and the Cedar Creek gas field in Montana; the Salt Creek and Lance Creek fields of Wyoming; and the Hobbs and Monument-Eunice fields of south-eastern New Mexico are best known. The principal features of each of these and many other fields of lesser importance have been briefly reviewed.

In the search for new fields, geophysical methods are regarded with favor, affording means of locating potential oil-bearing structures not readily identified by other means. Discoveries of new fields in the region have been infrequent during recent years, in comparison with the post-war decade during which exploration was more active. Since 1927, comparatively few new wells have been drilled and production declined from the peak of 47,653,000 bbl. reached in 1923, to only 14,800,000 bbl. in 1933. Since the latter year, production has again been increasing, reaching 22,166,000 bbl. in 1936. Gross oil production of the region to the end of 1936 has been 632,-495,000 bbl. and estimates made at this time of known reserves, producible by ordinary methods of flowing and pumping in fields discovered prior to 1937, are somewhat in excess of 800,000,000 bbl. Nearly two-thirds of the previous production of the region has come from the Wyoming fields and more than half of the visible reserves for the future are in New Mexico.

The refineries of the region are mostly small skimming plants of but a few hundred barrels daily capacity. Only seven have daily capacities of 5,000 bbl. or more. Most of the larger plants have modern cracking facilities. Further modernization of several

plants is now under way. The so-called green oils, chiefly used and preferred by the refiners of the region, yield an unusually high percentage of gasoline. The high-sulphur black oils, an abundant supply of wh ch is available in some districts, present unusually difficult refining conditions. A total of 106 oil refineries are situated in the region. Of these, 31 were idle in 1935. Gross crude refining capacity in 1935 was 102,-432 bbl. per day.

Upwards of 77,500,000,000 cu. ft. of natural gas are produced annually in the region and delivered to consumers. Most of the larger cities and towns are served with natural gas. Though there is a large reserve of undeveloped natural gas, a considerable part of that used, particularly in Colorado, is transmitted from fields in southern Kansas and northern Texas. On the other hand, some gas is shipped out of the region from fields in Montana to cities in North and South Dakota. The natural gasoline industry is relatively under-developed, there being but 15 extraction plants having an aggregate daily capacity of 286,300 gal. There are also important, but as yet undeveloped resources of helium and carbon dioxide.

Oil pipeline transportation facilities of the region are limited to 1,345 miles of gathering lines and 840 miles of main trunk pipelines. These lines are, for the most part, comparatively short and of small capacity. Distribution of both crude and refined products is primarily by the railroads, with which the region is well equipped.

In excess of 531,000,000 gal. of gasoline were consumed in the region in 1936. Roughly, about nine-tenths of this was produced from local refineries and one-tenth was imported from other districts. There are upwards of 5,400 service stations and 1,860 garages in the five Rocky Mountain states, engaged in retail selling of gasoline. Fuel oil and road oil and asphalt are also important products from the marketing stand-point.

As for the future, it seems probable that the Rocky Mountain province may someday assume a much more important place among the oil and gas producing regions of the United States than it does today. Because of the comparative inaccessibility to large markets and refining centers, it will probably be the last of the important oil-producing provinces in the United States to be intensively exploited. The region is sparsely settled and industrially under-developed, so that any great increase in market outlets during the near future, must be found in other surrounding states. Long rail hauls are costly and prohibit competition with the California, Mid-Continent and Gulf Coast industry. Except for movement of oil by pipeline from south-eastern New Mexico into the Gulf Coast region, and a small amount of Montana oil sold in Canada, there is at present, no exportation of crude to other regions. There is but one pipeline out of the region to the east and it has lately been unused. A crude oil pipeline from the producing districts of Montana and Wyoming through the Pacific northwest to Seattle or vicinity, has been considered and might be economically justified if the California supply should become more restricted or higher in price. Ultimately, the oil shale resources of the Rocky Mountain states promise to assume an important role in meeting the Nation's demand.

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International News & Notes

IMPORTS of Albanian crude into Italy for the first six months of 1938 amounted to 41,226 tons, a gain of 11,197 tons over the January-June period of 1937.

THE FIRST General Motors tank truck powered with the new G.M. Diesel engine, built to the order of Standard Oil Company of New Jersey, will be exhibited at the National Motor Truck Show in New York, during November.

IN ORDER to interest younger employees in production work done in Netherland India, the Royal Dutch Petroleum Company this summer arranged a petroleum exhibition at The Hague, including a complete drilling rig. Core drilling was carried down to 2,000 ft.

UNDER arrangements with an American group, a 140-mile pipeline will be built by the Capertee Petroleum Pty. Ltd., Sydney, Australia, from Baerami to Sydney for transportating crude shale oil to a refinery which will be constructed near Sydney. The refinery will cost about £600,000 ($3,000,000) and the pipeline about £450,000 ($2,225,000).

AZIENDA Italiana Petroli Albania is multiplying its activity in the Kuciovo and Devoli Valley oilfields and is extending its prospecting to new districts of Albania. Drilling progress in recent years is indicated by the following figures: 1934, 39,128 ft.; 1935, 69,970 ft.; 1936, 152,260 ft.; and 1937, 291,031 ft.

ITALIAN interests have revived discussion of the plan for constructing a 313 mi. pipeline from the oilfields near Ploesti, Roumania, to the Fiume terminal on the Adriatic. This is to eliminate the necessity for tankers to pass through the danger zone of the Dardanelles—from Turkey in the Straits and by other hostile powers in the Mediterranean.

AMERICAN Locomotive Company's arrangement with the Gyro Process Company, whereunder it acted as exclusive agent for the sale of licenses licensing the Gyro cracking process, has been terminated. Alco Products Division of the American Locomotive Company will now supply, in addition to its regular line of refinery eqiupment, any and all types of cracking equipment.

INTENSIFICATION of drilling in old and new fields in Roumania will be carried on by Phoenix Oil & Transport Company Ltd. and its subsidiaries in order to offset the unexpected drop in production in the two-year old Bucsani field, says F. W. Chambers, chairman. He states that the Runcu area now being explored looks hopeful as a new source of crude supply. In 1937 the company produced nearly 1,750,000 bbl. less oil than in the previous year.

DURING the first six months of 1938 France imported 3,822,100 metric tons of petroleum and products, compared with 3,892,280 tons during the corresponding period of 1937. Of these imports crude oil was reported as 3,206,030 tons and 3,109,080 tons respectively. The greatest quantity of crude oil came from the United States. Imports also came from Venezuela, Peru, Colombia, Ecuador, Roumania and Morocco.

EARLY in July the clearing agreement between Turkey and Roumania began to function so badly that imports of Roumanian petroleum products into Turkey have now practically ceased and the United States has again become Turkey's chief source of supply. In recent months it has again become possible for the Neft Syndicate to secure regularly from Russia the necessary supplies to conduct its business in Turkey, but this company distributes hardly more than 15 percent of the country's total trade.

THE FOUR oil wells in the Lispe field of Hungary are now producing about 130 tons daily while the Bukkszek field totals about 25 tons. Although little increase may be expected from the latter, a gradual but decided increase is anticipated at Lispe through the rest of 1938 and the first three-quarters of 1939; the estimates of production in this field made by the concessionaires indicate that by September, 1939, daily cutput will have risen to about 620 tons. As the total crude oil requirements of Hungary amount to 600 tons per day the Lispe field will, if developed according to plans, supply the entire demands of Hungary by that date. An additional 15 wells are to be drilled between September, 1938, and September, 1939, in order to reach the estimated production figures. Accomplishment of this plan will mean that imports of crude oil and all refined products except high-grade lubricating oils should practically cease after September, 1939. High-grade lubes cannot be refined in Hungary until the necessary plants are built and it is unlikely that they will be built before production of the entire domestic requirements is a fact.

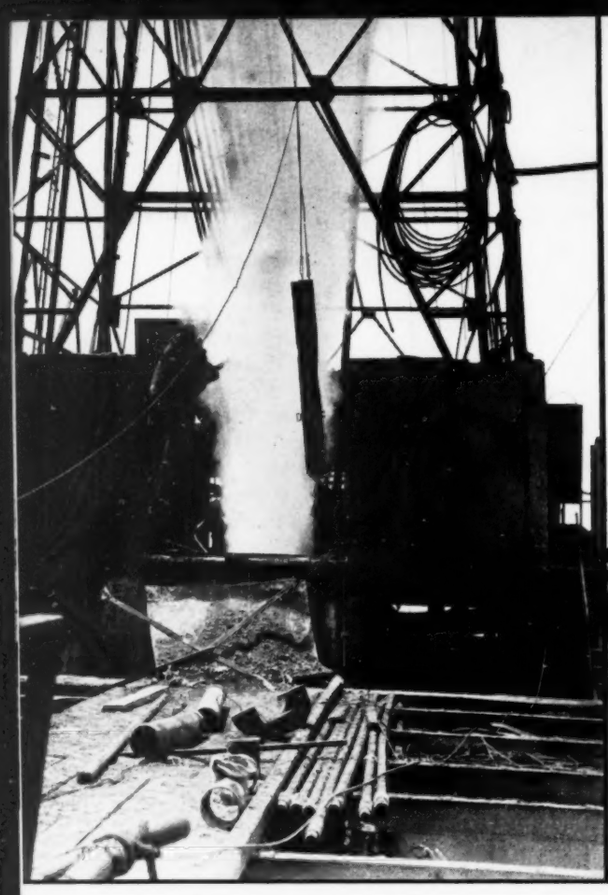
IT HAS BEEN revealed by British sources that Anglo-American Oil Company has commenced construction of underground storage facilities at its Purfleet terminal. This addition is in connection with national defence measures and will have a capacity of 1,000,000 bbl. of gasoline. The Minister of Transport recently approved the ammendments to the Port of London by-laws with respect to gasoline cargoes on the Thames. This means that as from August 31st, 1939, bulk cargoes of gasoline are no longer restricted to the Mucking Light but may go up to Crayfordness, just above Purfleet. This extension of the limit makes accessible to ocean-going tankers four additional terminals and is a great blow to the public storage installation at Thames Haven, formerly the highest up the river. Terminals coming within the new approved low test petroleum import limit for seagoing tankers are: Anglo-American Oil Company Ltd.'s installations at Gravesend, and (two) Purfleet; Shell-Mex and B.P. Ltd.'s installations at Shellhaven and Purfleet; London and Thames Haven Oil Wharves Ltd., at Thames Haven; Cory Bros. and Co., Ltd., near Shellhaven; and London and Coastal Oil Wharves Ltd., at Canvey Island.

SOME 43 naval and semi-naval tankships aggregating more than 312,500 tons deadweight are building and projected by the governments of a dozen nations. Building will probably be intensified during the next few years because the rate of naval construction is accelerating even faster than in that fatal pre-war competition for sea power. Addition of these 43 vessels, some of which will have speeds as high as 20 knots, will bring the total number to at least 296 vessels of more than 1,763,648 tons dw.

America will hold the leading position at the end of the present program with 34 oilers totaling over 427,966 tons dw. This includes the 12 high-speed tankers building with the financial assistance of the Maritime Commission.

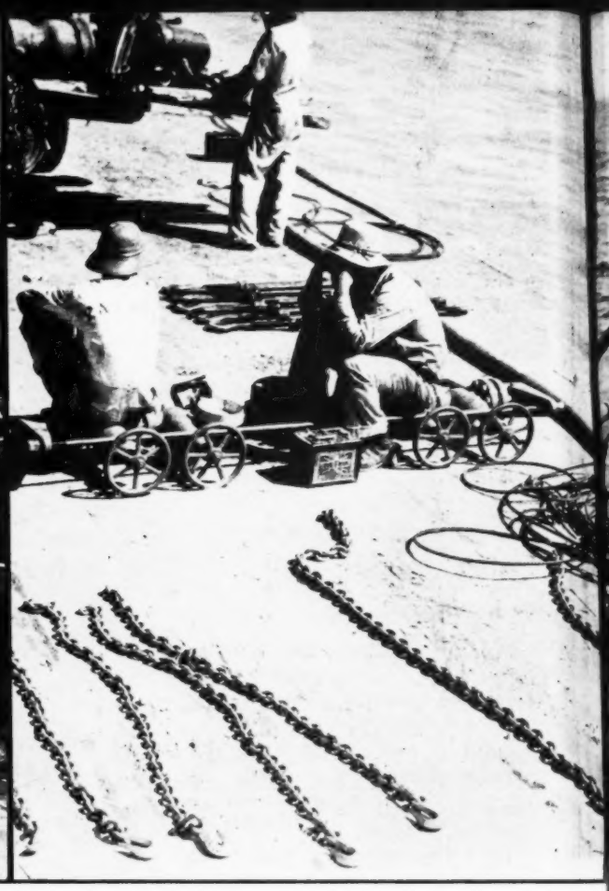
If the 21 high-speed tankers operated in commercial service by merchant shipowners are taken into consideration with the vessels of the Imperial Japanese Navy, the Nipponese come a close second to the U. S. with 36 tankers (23 exceeding 15 knots) totaling 410,300 tons.

Great Britain oilers are of a smaller unit size and although its fleet embodies 67 oilers it totals only 378,212 tons. Other large fleets are: Russia, 46 tankers (241,703 tons); Italy, 42 (154,861 tons); Loyalist Spain, 22 (125,646); and France, 25 (108,027).



Gas blowing through drilling barge—note derrick girth in foreground, cut out by sand and vibration.

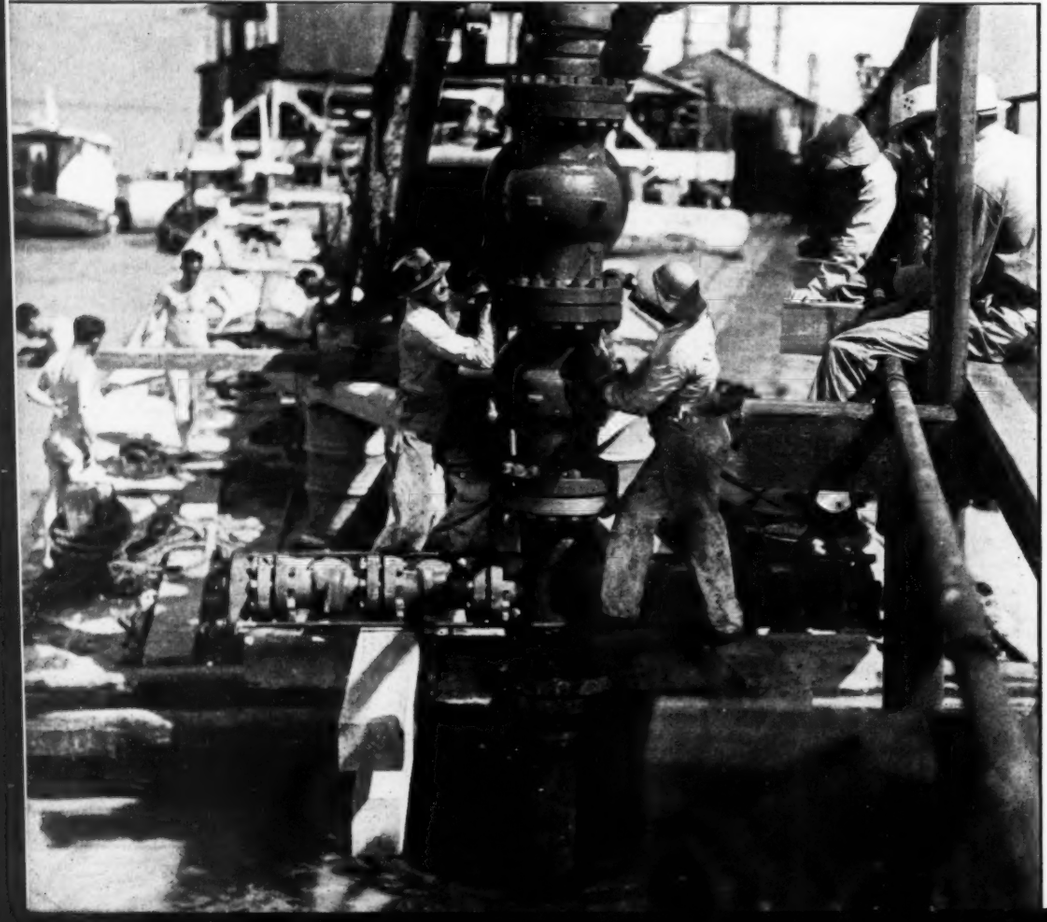
Christmas tree ready to move to the well; note Patton guide-point and tapered shut-off pipe.



Patton barge showing tie chains and cable in foreground—the men are snatching a rest and bite to eat before entering the most hazardous part of the work.

HARNESSING A BLOW-OUT

Tightening flanges on Christmas tree while some of Patton's crew enjoy a swim in Vermillion Bay. Wm. Patton, who was killed, is shown in the right foreground.



WHEN NATURE decides to kick over the traces, it takes a lot of fancy harness to get her back under control. The recent blow-out of a Vermillion Bay (La.) well which cost two lives and many thousands of dollars in property damage is a fair example.

While a drilling crew was engaged in drilling out the cement plug, after setting a string of casing at 9,667 ft., in a test about three miles off shore, the driller started pulling the drill stem out of the hole. About 3,000 ft. of the pipe was pulled out when things began to happen. Gas blew in a volume that increased so rapidly that the crew was unable to get the blow-out preventers closed before the sand, rushing out with the gas, had cut them to the point of uselessness. In a short time the well was completely out of control. The blast of sand and gas cut off the well-head connections, and the vibration started disintregation of the derrick.

Steel girths, bolts, nuts, filled the air. The roar of the gas prevented the possibility of giving orders by word of mouth, and the drilling crew talked back and forth with hand signals. Falling steel became too dangerous and the crew moved out until the drilling barge, derrick and all, could be floated and removed from over the well.

Patton barge moved into position at the well with Halliburton trucks and sacks of mud ready to pump into and kill the well.

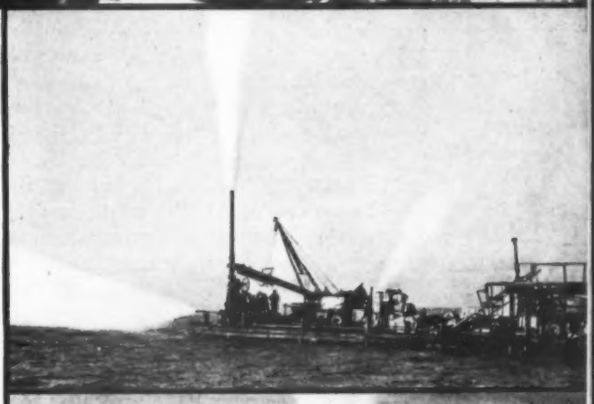
Upper right—Christmas tree being turnbuckled down; steam is playing on tree for fire prevention. All gas is blowing through the tree and stack. Right—four-inch side connection opened to relieve pressure while closing ten-inch gate valves.

Nothing further could be accomplished until a professional well fighting outfit was summoned from Houston, Texas. Fortunately the flow of sand stopped and only a huge column of gas and some fluid roared into the air—roared so loudly that it could be easily heard some 22 mi. away. With the cutting action of the sand eliminated, the gas did little further damage. Ideas for special equipment were worked out—hurry-up orders sent to the shops, and in a few days the capping attempt was under way.

A huge manifold with heavy valves over a stinger, suspended on the boom of a fire fighting truck, was moved inch by inch over the roaring well. Inch by inch the stinger was lowered in, the gas flowing through the open valves of the manifold. Once in place, and in imminent danger of horrible death, the special crew, with the assistance of the drilling crew, rigged heavy chains to fasten the manifold to the well casing. The chains were gradually tightened by turnbuckles until the gas was diverted almost entirely through the manifold. Then slowly against the tremendous pressure, the almost exhausted group started closing the valves. First one valve, then the other yielded until both were closed.

Halliburton pumps were brought into play and succeeded in getting some water into the well, but apparently could not build up enough pressure to kill it. Some leaks around the bottom of the manifold began to develop—became large enough to convince the workers that the attempt had failed. Exhausted and discouraged, they decided to cut loose from the well, let the gas cut the heavy manifold from the well-head and drop it into the bay. With this in mind, the crew started to flange on the stack used to prevent the gas from cutting the valves. Then hell broke loose. With a blast, the well burst the chains holding down the manifold and roared free into the air—on fire. One worker was knocked to the ground—dead. Another's burned body was found days later, over a mile from the well. A third had his right arm blown off near the shoulder. The well, bursting into flames when it exploded, was loose again. The slug of water already pumped in was thrown out, luckily extinguishing the fire a few seconds after the blast.

Regardless of temporary failure, a few days later, and with more equipment, the crew started again. This time they were successful. The well was finally capped, mud was pumped in, the well killed—and all is again quiet on the Vermillion Bay Front.



Upper right—Laying the mud line to the well. Right—Towing the equipment away after the job was finished.

Foreign Oil Legion

THE MAN who negotiated the southern Iraq oil concession for Basrah Petroleum Company, Ltd., subsidiary of the Iraq Petroleum Company Ltd., is JOHN SKLIROS, general manager in London for I.P.C. The agreement was signed at end of July between Mr. Skliros and SAYYID IBRAHIM KAMAL, Iraq Minister of Finance and Acting Minister of Economics. For the most part, the southern concession covers the area included in the old Turkish vilayet of Basrah, but excludes Khanakin, where an Anglo-Iranian Oil Company subsidiary operates. The I.P.C. thus has control of practically the whole of the oilfields in Iraq. Negotiations had been opened at the end of 1936 by CHARLES HART, former U. S. Minister in Teheran and negotiator of the Iranian and Afghan concessions, taken over by F. W. RICKETT (who originally held the B.O.D. concession) and now concluded by Mr. Skliros.

Mr. Skliros, known familiarly in European oil circles as "the Greek," is 55 years old, born in England of a Greek father and British mother. He first went to Iraq before the World War as mechanical engineer for a British water pump manufacturing concern. He entered Baghdad again as political officer with the British Expeditionary Force after occupation of the city. On discharge, he joined the staff of Anglo-Iranian (then Anglo-Persian) Oil Company, Ltd., and served in Iraq for three years—during which time he built Baghdad's first modern cinema. Returning to England, he became General Manager of Iraq Petroleum Company, Ltd. In that capacity he signed the agreement with the Iraq Government in 1931 which secured the Kirkuk oilfields concession for the I.P.C.

JOHANNES RINGERS, famous civil engineer of the Zuider Zee reclamation project in the Netherlands, sailed for New York on board the STATENDAM September 20th. Mr. Ringers was en route from Venezuela after an advisory mission to that country's government regarding the harbor at Maracaibo—for some time the channel to the harbor has been sanding up, with the result that the specially-designed lake tankers can no longer cross the bar loaded to maximum draft.

AIR MARSHAL SIR EDWARD ELLINGTON visited the Turner Valley oilfield last August following a trip through Australia, India, and California. He considers that Canadian oil would be of great importance to the British Empire in the event of war. The visit was made at the request of the HON. IAN MACKENZIE, Minister of Defense, and is of especial interest because it is reported that a pipeline will be built from that field to Vancouver. The oil would be used for British naval purposes: the Canadian goverment has no direct connection with the plan.

WARNER MELVIN, of the marine department of Standard Oil Company of New Jersey, sailed with Mrs. Melvin on board the WASHINGTON enroute to Europe, September 21st.

EUGENE HOUDRY, prominent in petroleum circles in Philadelphia, returned from a European trip on board the ILE DE FRANCE September 5th.

C. L. DURHAM, export manager of Sullivan Machinery Corporation is leaving New York in mid-October on a trip through the oilfields in Venezuela.

E. P. Pink, purchasing agent for Iraq Petroleum Company, Ltd., photographed at his desk in London. Mr. Pink is visiting New York and Chicago together with the company's transportation superintendent, C. C. Bampton.

J. E. J. Taylor

J. E. J. TAYLOR, a director of Société Générale des Huiles de Pétrole, recently left Paris to take up an administrative post in the London headquarters at Britannic House of the Anglo-Iranian Oil Company. Although he will be visiting Paris from time to time in his capacity as a director of his old company, Mr. Taylor's constant presence will, after his seventeen years sojourn there, be much missed by a wide circle of business and personal friends. His French associates especially will always remember him as a firm friend of their country.

JAY E. CRANE has been elected treasurer of Standard Oil Company (N.J.) succeeding R. P. RESOR, who recently retired after half a century of service. Prior to joining the Jersey company on May 1st, 1935, as assistant treasurer, Mr. Crane had spent 20 years with the Federal Reserve Bank of New York. He served as an unofficial observer at the conference which established the Bank for International Settlements, and was in London at the time of the World Economic Conference when efforts were made to stabilize the principal foreign exchanges. Much of the work which he supervised at the bank was undertaken for the Treasury Department at Washington, such as operations in gold, silver, and foreign exchanges. Since his affiliation with the Jersey Standard, Mr. Crane has visited all the principal operations of the company in Europe and South America.

M. DE BOULARD, technical director, Omnium International des Pétroles, Paris, France, has been visiting American refineries. Omnium's new refinery in Roumania recently was placed on stream.

WILFRED E. GOODAY, A.R.S.M., D.I.C., M. Inst. M.M., M. Inst. P., well-known in the British oil industry as an independent consulting petroleum technologist, has left England for an extended business visit to South Africa. He recently sailed from London with Mrs. Gooday on the liner UMTATA en route to Cape Town where he will open an office. Qualifying originally as a mining engineer and specializing as a petroleum technologist, Mr. Gooday has held administrative positions in both Roumania and in the West Indies, and for thirteen years was technical manager in London of the Vacuum Oil Company, Ltd., a post which he resigned in 1934 to take up private consulting practice. Concurrently with his work in England he served on the panel of the Court of Arbitration of the London Chamber of Commerce, and since 1933 has been a member of the Council of the Institute of Petroleum. During the war he was in charge of petroleum products under the Air Ministry, representing the Ministry in the United States as a member of an Inter-Allied Commission. Mr. Gooday originated the idea of running an oil pipeline along the Union canal bank from London to Birmingham in furtherance of national security. In light of similar developments in France it would not be surprising if the British government should yet adopt the plan. When Mr. Gooday is not working he spends his leisure moments with his collection of pipes from all parts of the world.

LESTER G. METCALF who for eight years has been manager of the refinery division of the Union Oil Company, has been appointed director of manufacturing. "Met", as his associates call him, has been connected with the Company since 1913, except during the 18 months he joined the war-time army. For many years he has been active on numerous technical committees of the A.P.I. and has a vast knowledge of refining technology.

B. T. W. VAN HASSELT, president of Cia. Mexicana de Petroleos "El Aguila" S. A., Mexico City, sailed for Europe on board the NIEUW AMSTERDAM, which left New York September 27th.

E. KENNETH SANDBACH sailed from New York on board the liner SANTA PAULA for Aruba where he and his bride will make their home. They were married September 17th at Paris Hill, Maine. Mrs. Sandbach is the former Alice Neale Gordon, daughter of George Gordon, Standard Oil Company of New Jersey executive. Mr. Sandbach, who graduated from Princeton in 1937, was one of the most famous of Princeton's football stars—he is now employed in the tank erection department of Chicago Bridge & Iron Works in Aruba.

Dr. Arthur Wade and Dr. W. G. Woolnough, prominent geologists associated with the Commonwealth government, Australia, during a recent conference at Canberra with Launcelot Owen, geologist to Papuan Apinaipi Oil Company.

PRINCE MOULAY HASSAN, nine-year-old heir to the Sultan of Morocco, recently visited the Shell ocean installation at Port-Lyautey as part of his education as a future ruler to familiarize him with the economics and industry of the country. The young prince took a keen interest, even requesting a detailed explanation of the reception and distribution of petroleum products.

MRS. R. I. Dodson, wife of the executive representative of Tropical and National Andian Companies in Bogota, accompanied by the Misses SUSAN and LOULITA DODSON, sailed from New York on the liner SANTA PAULA September 21st. Mrs. Dodson and her daughters are enroute to rejoin MR. DODSON, who made the trip to Bogota via Pan American and Scadta airways on July 28th. Mr. Dodson, on behalf of his companies, took a prominent part in the celebration of the Fourth Centenary of the city of Bogota and the inauguration of PRESIDENT EDUARDO SANTOS in August. National Andian and Tropical Oil companies presented a large and well-equipped playground to the city of Bogota.

MANUEL MIRANDA, manager of The Texas Company (Caribbean) Ltd., at Port-au-Prince, and Mrs. Miranda, have returned to Haiti after a visit to the United States and Canada.

D. A. SUTHERLAND, managing director of Emsco Engineering Works, England, is visiting the United States with Mrs. Sutherland on an inspection tour of the Emsco works in Los Angeles, Houston and Dallas. He expects to remain in America for several weeks.

C. S. SNODGRASS, who formerly represented C. F. Braun & Company of Alhambra, Calif., in London, and more lately managing-director of T.V.P. Ltd., has formed with MICHAEL PERRIN a new company known as Snodgrass, Perrin & Company Ltd., which will furnish specialized refinery services to oil companies that do not wish to organize a large engineering department in Europe. Also on the board of directors are E. L. FULLER and C. H. ARKWRIGHT, the latter representing the British banking group financially interested in the new concern.

A. Beeby Thompson, well-known British petroleum technologist, having tea with his daughter during a recent trip to Trinidad—of which country he was one of the early oil pioneers.

WORLD OIL

All figures furnished direct to WORLD PETROLEUM by governments, except where otherwise specified

U. S. BARRELS

	September 1937	October 1937	November 1937	December 1937	January 1938	February 1938	March 1938	April 1938	May 1938	June 1938	July 1938	Preliminary Figures August 1938
NORTH AMERICA—												
United States	109,980,000	110,911,000	104,206,000	106,579,000	106,007,000	94,662,000	106,524,000	102,702,000	98,674,000	94,277,000	102,898,000	104,300,000
Mexico	3,432,101	4,372,808	4,211,293	4,349,415	4,141,977	4,016,000*	900,000*	700,000*	1,700,000*	1,800,000*	2,000,000*	2,300,000
Canada[2]	298,753	342,452	341,517	408,580	457,408	413,158	480,803	464,316	566,086	537,654	693,332	700,000
Total North America	113,700,854	115,626,260	108,869,810	111,336,995	110,606,385	99,091,158	107,904,803	103,866,316	101,940,086	96,614,654	105,591,332	107,300,000
SOUTH AMERICA—												
Venezuela	17,640,872	17,979,227	17,044,016	17,096,298	15,271,902	13,792,479	15,109,040	13,696,219	15,994,400	16,302,150	14,912,555	15,000,000
Colombia	1,617,433	1,811,759	1,797,625	1,824,956	1,784,638	1,508,487	1,841,882	1,616,000[1]	1,804,000[1]	1,826,136	1,826,848	1,852,000
Trinidad	1,358,600	1,393,317	1,300,485	1,349,908	1,378,021	1,304,819	1,438,436	1,418,825	1,481,285	1,431,476	1,500,171	1,505,959
Argentina	1,369,767	1,360,000[1]	1,365,000[1]	1,370,000[1]	1,378,000[1]	1,289,000[1]	1,380,000[1]	1,349,000[1]	1,382,000[1]	1,346,000[1]	1,349,000[1]	1,360,000
Peru[3]	1,448,464	1,484,761	1,428,079	1,486,121	1,365,152	1,224,437	1,474,364	1,296,090	1,343,259	1,303,536	1,335,623	1,328,143
Ecuador	178,122	182,053	176,252	178,776	187,525	171,138	191,746	181,331	190,542	188,712	192,360	193,634
Bolivia	12,272	10,736	11,751	12,810	10,302	7,128	9,100[1]	8,800[1]	9,000[1]	8,790[1]	9,500[1]	9,200
Total South America	23,625,530	24,221,853	23,123,208	23,318,869	21,375,540	19,297,488	21,444,568	19,566,265	22,204,486	22,406,800	21,126,057	21,248,936
SOVIET UNION—												
Total U. S. S. R.[4]	16,663,000	17,600,000	16,923,000	17,600,000	17,647,000	13,591,000	15,984,000	17,850,000	17,580,000	18,540,000	18,200,000	18,000,000
ASIA & AFRICA—												
Iran[5]	7,198,034	7,075,122	6,821,616	5,999,642	5,907,458	6,414,470	8,284,215	7,090,486	6,975,256	5,792,228	6,920,000[1]	6,950,000
Netherland India	4,586,638	4,766,689	4,626,395	4,671,582	4,245,587	4,235,422	4,721,147	4,568,899	4,764,193	4,573,726	4,518,455	4,520,000
Iraq	2,513,145	2,663,244	2,645,099	2,431,532	2,670,844	2,385,464	2,717,278	2,592,996	2,332,746	2,653,579	2,806,903	2,829,528
Bahrein[6]	662,861	847,988	749,354	805,236	805,800	707,379	737,164	692,403	620,746[1]	661,602	699,176	713,149
Burma[7]	701,066	704,736	631,584	640,195	616,522	496,306	633,644	637,000[1]	652,000	635,000[1]	638,000[1]	635,000
Brunei[8]	341,111	351,711	376,487	405,623	409,592	381,052	445,194	428,829	445,505	425,184	453,393	465,000
Japan[9]	205,914	210,228	214,330	211,436	218,594	214,191	214,820	207,522	216,078	216,707	216,707	217,000
British India[10]	173,150	181,089	197,043	210,360	196,697	132,164	197,792	187,000[1]	193,000[1]	187,000[1]	195,000[1]	200,000
Sarawak[11]	134,311	133,684	126,439	131,901	137,497	126,578	137,281	133,248	137,824	132,240	132,007	133,000
Egypt[12]	100,699	97,203	95,082	94,509	91,927	84,974	94,545	88,555	89,935	84,998	83,412	105,000
Total Asia	16,616,929	17,031,694	16,483,429	15,602,016	15,300,518	15,178,000	18,183,080	16,626,938	16,427,283	15,362,264	16,663,053	16,767,677
EUROPE—												
Roumania	4,256,000	4,313,000	4,162,000	4,198,000	4,099,000	3,751,692	4,182,000	4,090,000	4,169,000	4,015,000	4,115,000	4,110,000
Great Germany: Old Reich[13]	282,155	288,926	272,665	277,551	268,028	257,967	355,684	342,387	329,688	326,842	346,435	347,000
Ostmark[14]	16,555	17,101	18,620	20,850	25,620	28,160	30,070	29,100	32,845	30,000[1]	29,000[1]	31,000
Poland	310,780	325,940	318,360	325,940	318,928	293,232	327,077	315,768	324,803	315,381	314,000[1]	318,000
Albania[15]	.....	.....	.....	.....	42,400	39,200	42,400	41,000	42,400	72,300	46,049	51,000
France	41,004	42,339	42,639	42,368	41,560	40,840	43,589	42,839	42,000[1]	43,189	42,000[1]	43,000
Hungary	.....	.....	1,930	11,980	13,744	12,451	13,976	13,000[1]	14,000[1]	13,000[1]	14,000[1]	14,000
Czechoslovakia	9,667	10,865	12,297	11,734	11,070	10,437	12,158	10,731	10,960	10,159	9,333	9,300
Italy	8,694	9,233	8,565	8,493	9,048	7,969	9,612	9,459	9,563	8,646	9,378	9,300
Total Europe	4,924,855	5,007,404	4,837,076	4,896,916	4,829,398	4,441,928	5,016,566	4,894,284	4,975,259	4,834,517	4,925,195	4,932,600
OTHER COUNTRIES[16]—												
Total Other Countries	5,800	6,000	5,800	6,000	6,000	5,400	6,000	5,800	6,000	5,800	6,000	6,000
WORLD TOTAL—	175,536,968	179,493,211	170,602,323	172,760,796	165,764,841	151,604,974	168,539,017	162,809,603	163,133,114	157,764,035	166,511,637	168,255,213

1 Estimate.
2 Includes natural gasoline production.
3 International Petroleum Company and Lobitos Oilfields Ltd. figures combined.
4 Russian Sakhalin included with U.S.S.R.
5 Anglo-Iranian Oil Company Ltd. figures revised—fuel oil returned to the ground has been deducted.
6 Behrein Petroleum Company Ltd. figures.
7 Does not include Assam or Punjab, which are listed together under British India.
8 British Malayan Petroleum Company Ltd. figures.

Official Crude Oil Production Figures for 1932 to 1937 (Revised)

	Jan.-Aug. 1938	Jan.-Aug 1937	1937	1936	1935	1934	1933	1932
NORTH AMERICA—								
United States	810,044,000	845,977,000	1,277,653,000	1,098,516,000	996,596,000	908,065,000	905,636,000	785,159,000
Mexico	17,557,977	30,090,070	46,455,687	41,027,915	40,240,563	38,171,946	34,000,830	32,805,496
Canada	4,312,757	1,491,270	2,995,025	1,507,931	1,447,204	1,410,895	1,145,333	1,044,412
Total North America	832,914,734	877,558,340	1,327,103,712	1,141,051,846	1,038,283,767	947,647,841	940,802,163	819,008,908
SOUTH AMERICA—								
Venezuela	120,078,745	117,533,321	187,675,477	155,270,840	148,809,057	136,098,681	117,113,940	115,615,782
Colombia	14,059,991	13,245,770	20,297,543	18,756,110	17,597,655	17,337,900	13,156,126	16,415,214
Trinidad	11,458,992	10,100,192	15,502,989	13,237,030	11,671,224	10,894,363	9,561,353	10,126,121
Argentina	10,833,000	10,771,143	16,354,717	15,457,960	14,297,025	14,021,901	13,690,556	13,138,747
Peru	10,670,604	11,557,910	17,459,112	17,593,069	17,056,555	16,314,381	13,257,318	9,899,265
Ecuador	1,496,988	1,446,136	2,161,436	1,942,467	1,731,785	1,636,619	1,619,902	1,597,641
Bolivia	71,820	75,561	10,302	104,746	163,295	157,875	111,973	41,907
Total South America	168,670,140	164,730,033	259,461,576	222,362,222	211,326,596	196,461,720	168,511,168	166,834,677
SOVIET UNION—								
Total U. S. S. R.	137,392,000	134,070,661	201,856,661	199,635,921	184,008,033	175,635,783	155,596,429	155,927,997
ASIA & AFRICA—								
Iran	54,334,113	51,008,480	78,109,001	62,977,950	57,520,488	57,902,092	54,440,075	49,316,697
Netherland India	36,147,429	36,146,817	54,112,933	47,961,744	45,307,913	45,107,828	41,234,498	37,988,913
Iraq	20,989,338	20,703,438	30,603,660	29,913,150	27,410,983	7,639,849	1,094,915	871,840
Bahrein	5,637,419	2,973,197	7,762,264	4,644,635	1,264,807	285,072	31,377	902
Burma	4,943,472	5,450,000[1]	7,847,553	7,587,718	7,181,113	7,278,859	7,114,311	7,073,437
Brunei	3,453,749	2,948,680	4,397,038	3,296,938	3,302,905	2,705,350	2,035,656	1,200,026
Japan	1,721,619	1,645,933	2,487,841	2,403,072	2,294,878	1,872,837	1,504,412	1,683,439
British India	1,488,653	1,480,000[1]	2,161,653	1,978,329	2,037,810	1,921,863	1,628,803	1,743,878
Sarawak	1,069,675	1,076,259	1,655,565	1,547,882	1,776,593	1,942,591	2,206,815	2,329,733
Egypt	723,346	761,307	1,163,267	1,262,666	1,255,151	1,527,252	1,653,535	1,071,976
Total Asia	130,508,813	124,194,111	190,300,775	163,574,084	149,352,641	128,183,593	112,944,397	103,480,841
EUROPE—								
Roumania	32,531,692	35,247,000	52,170,000	63,532,846	61,270,072	61,849,306	53,919,708	53,651,978
Great Germany: Old Reich	2,574,031	1,990,000[1]	3,148,300	3,076,858	2,967,438	2,204,402	1,656,602	1,594,807
Ostmark	235,795	146,000[1]	221,266	50,092	44,347	27,965	5,765	804
Poland	2,527,189	2,497,660	3,799,862	3,869,575	3,901,881	4,011,336	4,174,079	4,219,634
Albania	376,749	290,000[1]	591,677	219,693	41,218	17,500	11,437	9,212
France	339,017	335,085	507,067	534,063	529,664	700,000	786,366	755,146
Hungary	108,171	Nil	13,910	100	Nil	Nil	Nil	Nil
Czechoslovakia	84,148	79,165	122,790	126,603	136,580	177,797	121,695	126,603
Italy	72,975	79,816	114,801	129,653	128,615	162,449	213,534	242,563
Total Europe	38,849,767	40,664,726	60,689,673	71,539,483	69,019,815	69,150,755	60,889,186	60,600,747
OTHER COUNTRIES—								
Total Other Countries	47,000	46,400	70,000	37,100	32,300	64,000	54,100	73,300
WORLD TOTAL—	1,308,382,454	1,341,264,271	2,039,482,399	1,798,200,656	1,652,023,152	1,517,143,692	1,438,797,443	1,305,926,470

PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries

METRIC TONS

	Sept. 1937	Oct. 1937	Nov. 1937	Dec. 1937	Jan. 1938	Feb. 1938	Mar. 1938	Apr. 1938	May 1938	June 1938	July 1938	Preliminary Figures Aug. 1938
NORTH AMERICA—												
United States	14,888,317	15,014,349	14,106,674	14,427,914	14,345,022	12,814,670	14,420,469	12,916,610	13,357,804	12,762,583	13,929,606	14,120,000
Mexico	509,516	649,110	625,192	647,196	614,902	596,200*	133,600*	103,900*	252,300*	267,700*	297,000*	355,000
Canada[2]	37,740	43,262	43,143	51,614	57,783	52,193	60,739	58,649	71,511	67,934	87,586	88,400
Total North America	15,435,573	15,706,721	14,775,009	15,126,724	15,017,707	13,463,063	14,614,808	13,079,159	13,681,615	13,098,217	14,314,192	14,563,400
SOUTH AMERICA—												
Venezuela	2,606,899	2,630,106	2,518,696	2,526,422	2,256,820	2,038,197	2,232,753	2,023,972	2,363,588	2,409,066	2,205,195	2,215,000
Colombia	225,425	253,904	250,540	254,349	248,730	210,242	256,700	225,000[1]	251,000[1]	254,514	254,669	258,000
Trinidad	191,190	196,076	183,012	189,967	193,923	183,622	202,425	199,666	208,456	201,446	211,113	211,928
Argentina	195,151	194,000[1]	194,000[1]	195,000[1]	196,300[1]	183,600[1]	198,000[1]	192,200[1]	196,900[1]	191,900[1]	192,200[1]	193,800
Peru[3]	191,950	196,761	189,250	196,942	180,911	162,263	195,383	171,759	178,010	172,745	168,725	176,006
Ecuador	25,244	25,801	24,965	25,377	26,577	24,254	27,175	25,699	27,004	26,743	27,262	27,412
Bolivia	1,544	1,350	1,478	1,611	1,295	897	1,140[1]	1,110[1]	1,130[1]	1,100[1]	1,200[1]	1,160
Total South America	3,437,403	3,487,998	3,361,941	3,389,668	3,104,556	2,803,175	3,113,576	2,839,406	3,226,088	3,257,514	3,060,364	3,083,306
SOVIET UNION—												
Total U.S.S.R.[4]	2,290,000	2,410,000	2,320,000	2,410,000	2,421,000	2,440,000	2,192,000	2,448,000	2,411,000	2,343,000	2,497,000	2,470,000
ASIA & AFRICA—												
Iran[5]	942,929	936,657	903,318	794,277	782,073	849,195	1,096,726	938,691	923,436	766,818	917,000[1]	920,000
Netherland India	615,655	639,824	620,994	627,058	602,510	568,513	633,711	613,275	639,489	613,923	606,504	607,000
Iraq	336,973	357,099	354,666	326,030	358,118	319,853	364,344	347,948	312,771	355,803	376,415	379,395
Bahrein[6]	90,703	116,036	102,539	110,186	109,751	95,450	100,478	94,457	84,723	90,435	95,428	97,279
Burma[7]	96,930	97,299	87,199	88,388	85,120	69,240	91,765	88,000[1]	90,000[1]	87,800[1]	87,900[1]	87,800
Brunei[8]	44,730	46,120	49,500	53,110	54,623	49,965	58,376	56,230	58,416	55,552	59,464	60,000
Japan[9]	29,303	29,917	30,502	30,089	30,070	30,481	30,586	29,518	30,750	30,839	30,839	31,000
British India[10]	21,983	25,002	27,205	29,040	27,157	18,247	27,308	25,100[1]	26,700[1]	24,900[1]	27,000[1]	27,600
Sarawak[11]	17,350	17,530	16,580	17,270	18,337	16,597	18,001	17,472	18,072	17,340	17,309	17,500
Egypt[12]	13,681	13,530	13,593	13,511	13,365	12,005	13,516	12,660	12,642	12,151	11,924	15,000
Total Asia	2,210,237	2,279,014	2,206,096	2,088,959	2,081,124	2,029,546	2,434,811	2,223,351	2,196,999	2,055,561	2,229,783	2,242,574
EUROPE—												
Roumania	583,014	590,822	570,137	575,068	559,973	512,175	570,239	558,362	568,874	548,139	561,775	561,000
Great Germany: Old Reich[13]	40,639	41,614	39,272	39,977	38,604	37,155	51,517	49,314	47,485	47,075	49,897	49,900
Ostmark[14]	2,365	2,443	2,570	2,850	5,816	5,253	5,820	5,627	4,900	5,800[1]	5,600[1]	5,850
Poland	41,000	43,000	42,000	43,000	42,075	38,685	43,150	41,658	42,850	41,607	41,000[1]	42,000
Albania[15]	.....	.....	.....	.....	6,200	5,650	6,200	6,060	6,200	10,790	6,873	7,150
France	5,756	5,929	5,971	5,933	5,820	5,579	6,104	5,999	5,900[1]	6,048	5,900[1]	6,000
Hungary	.....	.....	250	1,550	1,778	1,612	1,808	1,700[1]	1,800[1]	1,700[1]	1,800[1]	1,800
Czechoslovakia	1,412	1,587	1,786	1,714	1,617	1,526	1,776	1,566	1,601	1,484	1,521	1,500
Italy	1,080	1,147	1,064	1,055	1,124	990	1,194	1,175	1,188	1,074	1,164	1,150
Total Europe	675,266	686,542	663,050	671,147	663,007	608,625	687,808	671,461	680,798	663,717	675,530	676,350
OTHER COUNTRIES[16]												
Total Other Countries	800	900	800	900	850	770	850	830	850	830	850	850
WORLD TOTAL	24,049,279	24,571,175	23,326,896	23,687,398	23,288,244	21,345,079	23,043,853	21,262,207	22,197,350	21,618,839	23,777,719	23,036,480

[9] Japanese Sakhalin, Taiwan (Formosa) and Hokkaido included with Japan.
[10] Excluding Burma.
[11] Sarawak Oilfields Ltd. figures.
[12] Anglo-Egyptian Oilfields Ltd. figures.
[13] Prussia, Thuringia and Baden.
[14] Formerly known as Austria.
[15] Italian imports of Albanian crude oil.
[16] Nominal figure representing proportion to world total represented by: Morocco, Cuba, New Zealand, Barbados, Greece, Algeria, Yugoslavia, Australia, Great Britain, and China.
* Estimated by competent private sources in Mexico.

Official Crude Oil Production Figures for 1932 to 1937 (Revised)

	Jan.-Aug. 1938	Jan.-Aug. 1937	1937	1936	1935	1934	1933	1932
NORTH AMERICA—								
United States	108,666,764	114,521,730	172,822,797†	148,707,864	134,912,143	122,913,903	122,601,191	106,289,292
Mexico	2,620,602	4,467,053	6,896,657†	6,090,842	5,973,955	5,666,857	5,049,109	4,870,175
Canada	544,795	201,019	378,430	190,495	182,820	178,233	144,686	131,937
Total North America	111,832,161	119,189,802	180,097,884	154,989,201	140,968,918	128,757,993	127,794,986	111,291,404
SOUTH AMERICA—								
Venezuela	17,744,591	17,434,135	27,733,926	22,945,299	21,990,373	20,112,115	17,293,193	17,085,334
Colombia	1,958,855	1,846,100	2,844,251†	2,614,092	2,452,635	2,416,432	1,833,606	2,287,835
Trinidad	1,612,579	1,421,361	2,181,676	1,862,796	1,642,446	1,533,122	1,345,532	1,425,009
Argentina	1,544,900	1,534,582	2,330,063	2,202,304	2,036,903	1,997,706	1,950,499	1,871,882
Peru	1,405,802	1,529,762	2,313,691	2,331,454	2,260,903	2,161,990	1,756,867	1,311,856
Ecuador	212,126	204,951	306,326	275,293	245,434	231,947	229,578	226,423
Bolivia	9,032	9,505	15,487	13,197	20,540	19,858	14,085	5,284
Total South America	24,487,885	23,980,396	37,725,420	32,244,435	30,649,234	28,473,170	24,413,360	24,213,623
SOVIET UNION—								
Total U.S.S.R.	19,422,000	18,391,029	27,867,025†	27,384,900	25,241,100	24,092,700	21,330,100	21,389,300
ASIA & AFRICA—								
Iran	7,193,939	6,746,240	10,340,648	8,337,487	7,614,897	7,665,507	7,207,180	6,555,387
Netherland India	4,884,925	4,757,238	7,263,481	6,437,818	6,081,599	6,054,742	5,534,832	5,099,183
Iraq	2,814,647	2,748,400	4,126,185†	4,079,066	3,724,231	1,048,108	147,943	118,887
Bahrein	768,001	406,773	1,058,557	635,555	173,072	39,008	4,293	123
Burma	687,625	702,748	1,083,391	1,047,593	991,456	1,004,951	982,233	976,589
Brunei	452,626	391,801	576,545	470,991	471,842	386,478	290,808	171,432
Japan	244,083	235,082	354,040	341,976	326,580	266,520	212,667	239,567
British India	204,012	186,431	298,450	273,137	281,072	265,341	224,879	240,767
Sarawak	140,628	143,529	217,085	221,126	253,799	277,513	315,259	332,819
Egypt	103,263	110,686	166,298	177,491	176,436	214,671	232,437	265,055
Total Asia	17,493,749	16,428,928	25,484,680	22,112,240	20,094,984	17,222,839	15,152,531	13,999,809
EUROPE—								
Roumania	4,440,537	4,775,219	7,146,575†	8,704,000	8,394,000	8,473,353	7,387,000	7,350,321
Great Germany: Old Reich	370,947	291,949	453,451†	444,600	427,400	317,500	238,600	229,700
Ostmark	44,666	22,647	33,010	7,473	6,616	4,172	860	120
Poland	333,025	332,000	501,301	510,630	514,760	529,200	550,670	556,680
Albania	55,123	42,475	88,310	32,760	6,152	2,500	1,707	1,375
France	47,350	46,882	71,008	74,788	74,172	98,025	110,120	105,758
Hungary	13,998	Nil	13,910	13	Nil	Nil	Nil	Nil
Czechoslovakia	12,591	11,535	17,936	18,665	19,946	25,971	17,776	18,493
Italy	9,059	9,915	14,261†	16,106	15,977	20,180	26,526	27,046
Total Europe	5,327,296	5,532,622	8,339,762	9,809,035	9,459,023	9,470,903	8,333,259	8,289,493
OTHER COUNTRIES—								
Total Other Countries	6,680	6,800	10,000	5,300	4,600	9,100	7,700	10,500
WORLD TOTAL—	178,569,771	183,529,577	279,524,771	240,545,111	226,417,859	208,026,705	197,031,936	179,194,129

†Preliminary total.

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing With Technical and Economic Aspects of the Petroleum Industry. Edited by Dr. O. W. Willcox

GEOLOGY

Oil and Gas Possibilities in the Atlantic Coastal Plain from New Jersey to Florida—Olive C. Postley, in BULLETIN AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, Vol. 22 (1938), No. 7, pp. 799-815.

On account of recent interest in oil possibilities in parts of the Atlantic Coastal Plain, especially southern Georgia and Florida, this paper gives a summary of the known general geologic features of states along the Atlantic Coast from New Jersey to Florida and of wells drilled in the region to depths of 1,000 ft. or more. No oil in commercial amounts has been found in the Atlantic Coastal Plain, and the aggregate thickness of the Cretaceous and Tertiary sediments in most parts of it is not sufficient to encourage the hope that oil pools will be found; in fact, wells at several places have encountered basement rocks at shallow depths. In southeastern Georgia and southern Florida, however, where only a few deep wells have been drilled, the basement rocks lie at greater depths, and the deeply buried Cretaceous and Tertiary formations are little known. Further drilling will be required to determine their character and to test their oil possibilities.

Criteria for Determining the Time of Accumulation Under Special Circumstances—Stanley C. Herold, in BULLETIN ASSOCIATION OF AMERICAN PETROLEUM GEOLOGISTS, Vol. 22 (1938) No. 7, pp. 834-851.

Peculiar structural locations for accumulations so frequently noted in the region extending from north Texas to the province of Ontario have puzzled geologists. Anticlines with barren crests have condemned flanking lands only to have them proved productive years later. Terraces were ignored until found productive by chance. Shallow synclinal areas were condemned without drilling, and they frequently have been found prolific afterwards. Obviously some one on each occasion suffered financial losses. But at a later time others gained.

In the geological profession these odd occurrences had evil effect. Not only were individual geologists awarded demerits for improper judgment, but the profession itself was often looked upon with disdain because of repeated failures. And more than that—they were, from 1865 to 1885, a challenge to the anticlinal theory of accumulation.

It is a fact that if all oil accumulations were of the class found in Pennsylvania, West Virginia and New York the anticlinal theory might still be seriously questioned. However, such odd occurrences are far less frequent than normal occurrences, and are explainable when the whole sequence of geological events is taken into consideration.

Application of Principle of Differential Settling to Tracing of Lenticular Sand Bodies—John L. Rich, in BULLETIN AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, Vol. 22 (1938), No. 7, pp. 823-833.

Because sand is much less compactible than clay, thick lenses of sand surrounded by shale, when buried under a load of later sediments, are marked by low anticlinal bulges. This principle has been used successfully for several years in Kansas for tracing lenticular sand bodies of both the channel and the offshore-bar types. Extremely detailed structural mapping is necessary to reveal these bulges, and they cannot always be distinguished from similar structures produced by other causes. Good exposures of evenly bedded rocks at the surface are essential, and lenticular sands at horizons above that at which production is sought may be a source of confusion. Elimination of regional dip is a valuable aid in interpretation. While it seems that every thick sand body is represented by a bulge, not every structural feature which might be so interpreted represents a buried sand body. Consequently, the experience and judgment of the geologist play a large part in the successful use of this method.

Scanlan (or Midway) Dome Lamar County, Mississippi—D. J. Munroe, in BULLETIN AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, Vol. 22 (1938), No. 7, pp. 816-822.

The Scanlan, or Midway, dome is 14 mi. south of west of Hattiesburg, in Lamar County, Mississippi. The approximate center of the dome is in Sec. 28, T. 4N., R.15 W. It is 110 mi. northeast of the Sorrento dome in Ascension Parish, Louisiana, the closest producing coastal salt dome. The only other salt dome discovered to date in Mississippi is 96 mi. northwest of the Midway dome, in western Hinds County.

Early interest in the area resulted from subsurface correlation between widely separated dry holes. Core drilling and test wells have revealed a domed structure elongate northeast and southwest with several hundred feet of closure. Several wells have found anhydrite and salt.

The Midway dome is a geological prospect. The stratigraphic section of the Eocene does not differ much from that normal for the area unless it is in the scarcity of sand bodies of any consequence. Structurally this is a piercement-type dome, belonging, in the writer's opinion, in the inland rather than the coastal classification. Salt movement had its maximum development in late Tuscaloosa or pre-Eutaw time, but continued until late Oligocene time. The oil accumulation that resulted in the asphaltic sand took place prior to the close of Tuscaloosa time.

The Asphalt of Taipu—S. Froes Abreu, in REVISTA DE CHIMICA INDUSTRIAL (Rio de Janeiro) vol. 7 (1938), No. 72, pp. 147-151.

Asphalt is found in fissures of calcareous rocks on the island of Taipu-Mirim in the Marahu river (Bahia). The deposits are of no commercial importance, but have attracted especial attention as a possible indication of petroleum at lower depths (being without known oilfields the Brazilians are particularly anxious to find petroleum deposits). However, the real nature of the Taipu-Mirim material has been open to question; on the one hand it might be an alteration product of natural petroleum, and on the other it may have resulted from metamorphism of the algal peats and lignites of the region. Analysis of the ash-free product shows it to consist of 39.1 percent of petrolenes and 61.9 percent of asphaltenes. Hence it must have derived from natural petroleum, and very likely oil might be found in the lower formations.

GEOPHYSICS

Soil Analysis in Geophysics—Mitchell Tucker in OIL & GAS JOURNAL, vol. 37 (1938), No. 6, pp. 20-39-106.

Agricultural chemists have long been accustomed to ascertain the fertility of a soil by boring into it with a hand augur to a depth of 10 in. to three feet and analyzing the sample of soil obtained in this manner.

It has lately been proposed to analyze samples of the surface soil to obtain indications as to whether the underlying deeply buried formations contain oil or gas.

At first sight this may appear to many people as a very silly idea. It is well known that oil and gas are held in underground traps, which generally consist of a layer or stratum of porous sand or rock that is overlain by an impervious layer of shale or some other kind of formation lacking porosity. The essential feature of an oil sand or pay formation is that it does not allow the oil to escape, keeping it imprisoned for perhaps millions of years until the impervious cap is penetrated by a drill. Since most oil and gas sands are deeply buried in many cases thousands of feet, it is difficult to imagine how oil could possibly diffuse through this enormous overlying burden and be found in appreciable quantities in the surface soil.

However, it is a fact that the surface soil over at least some oilfields does contain significant traces of hydrocarbons. If the oil does not ascend through the supposedly impervious capping, it may find a more or less easy path where the formations have been affected by faulting, folding or other subsurface abnormality. Sometimes this outward movement of oil or gas becomes visible as seeps, in other cases the presence of paraffin in the soil is distinctly apparent; and where such visual evidence is lacking it has been found that the soil in the immediate vicinity of oil bearing salt domes contains stronger traces of petroleum than soil more remote from the place where the upthrusting salt has disturbed the geological formations.

At any rate, the connection between traces of hydrocarbons in the surface soil and deposits of oil in the underlying formations has been found sufficiently close to warrant adding soil analyses to the repertory of the oil geologist and the geophysicist.

In exploring a suspected terrain crews of soil samplers run a network of lines by taking soil samples every 500 ft. and send them to the laboratory for analysis, and from the results conclusions are drawn.

This aid to the oil geologist or geophysicist is not an exact science, but is more or less useful in interpreting data obtained by other methods.

Core Testing by Radioactive Methods—H. Landsberg and A. I. Ingham, in OIL WEEKLY, vol. 90 (1938) No. 4, pp. 26-28.

The fact that radon (RaEm) readily dissolves in petroleum led to the idea of investigating the radioactive properties of oil-bearing strata. Measurements of the ionization in oil wells by Hummel had shown very strong activity near the horizons acting as oil reservoirs. Belluigi, in a paper dealing with helium sources and the radioactivity connected with oil, suggested prospecting for such deposits by radioactive methods. It was therefore thought that by inspecting cores for their radioactive properties, an additional method of analysis might be made available.

Most rocks contain a certain, though very small, amount of radioactive material. Radon, one of the products of radioactive disintegration, is a gas and therefore is able to diffuse readily through porous structures. Any accumulation of oil, acting as a solvent, would tend to enrich itself with radioactive material.

Since the disintegration would continue, the following products of radon, namely RaA through RaG—all solids—would partly stay, in the particular horizon, even though the oil might be removed. This secondary concentration of radioactive substances, as well as any possible primary differences in radioactive constituents of the strata, if measurable, should prove an aid in correlating horizons.

With the foregoing as a working hypothesis, measurements of oil sandstones were started in the spring of 1937.

The net result of work on cores from Bradford (Penna.) is the finding that within relatively small thicknesses of layers considerable differences in radioactive effects can be observed. It should be possible to furnish proof that such differences are consistent over a large area, a sensitive criterion for the correlation of horizons may be available.

Newer Trends and Methods in Geophysical Petroleum Exploration—J. Brian Eby, in PETROLEUM ENGINEER, vol. 9 (1938), No. 10, pp. 31-34-37.

This review is principally a discussion of two newer developments in petroleum prospection. One is the method of making electric transients (Eltran). Anomalies observed in this way are said to represent the mineralization that occurs over buried structure. It is believed that this mineralization affects the distribution of hydrocarbons seeping from the underlying deposit, resulting in the halo pattern of gas seeps that was responsible for the discovery of Goose Creek in 1906 and was also observed at Humble, Sour Lake, and several other fields prior to their discovery. This mineralization appears to be a good index of the presence and lateral extent of structures of very low relief.

The method of an Eltran survey is to establish a line of electrode stations where shallow holes are dug and filled with a salt solution to increase the conductivity; a sample of soil from the hole is reserved for future use as mentioned below. Electrical readings are taken between each hole and a central station by means of long cables. By observing the "time constant" of the electromotive force in these measurements it is possible to plot structures.

The samples of soil removed from the electrode holes in the electrical survey are analyzed for the presence of hydrocarbon gases (ethane and higher). Such soil analyses are becoming of increasing interest because gas seeps have frequently been observed over buried oil deposits. Two significant patterns of such accumulations of gas in the soil are recognized. One group is narrow and elongate, coinciding with the surface traces of faults that intersect reservoirs. The other group takes the form of rings, or halos, inside and outside of which low values (ethane counts) are found. The recognition of such a pattern of macro gas escapes led to the discovery of production in the Goose Creek oil field, for inside the halo no gas escapes were observed and outside the halo no production was found. It is interesting to note that, although about 30,000,000 bbl. of oil were produced from that field from sands as shallow as 1,400 ft., the observed gas escapes were around the edges of the field rather than over the top of the field. About the same time, similar patterns of gas escapes were noticed at Humble, Spindletop, Sour Lake, and Pierce Junction prior to the discovery of oil at these structures.

The particular field for Eltran surveys and soil analysis appears to lie in detecting oilfields characterized by vanishingly small structural relief that are difficult to indicate by other methods.

DRILLING

Advancements in Acidizing Wells—W. W. Love in PETROLEUM ENGINEER, vol. 9 (1938), No. 10, pp. 25-28.

The principal improvements in acid treatment of oil wells discussed in this paper include organic gel plugs designed to localize the effect of the acid; that is, to confine it to the exact zone where its solvent action is most desired. Thus, a bottom plug is used to prevent migration of the acid into lower thief sands. Such plugs, which are at first fluid but later harden, are also used to plug intercalated sand layers in the horizon to be treated. When all thief zones are thus sealed the acid is allowed to act; subsequently the organic gel is destroyed by bacterial action, and everything is opened up again.

Another recent advance is stage treatment which is based on the fact that after the acid has acted on a dense limestone or dolomite it loses its acidity and becomes more viscous on account of the presence of neutral salts in solution; higher pressures are therefore required to force fresh acid back into the formation, with the result that the operation is time-consuming and frequently unsatisfactory. This is obviated by applying the acid in successive portions or stages; the spent acid at the end of each stage is removed and immediately replaced by fresh, and so on until the desired result is accomplished. A considerable economy of acid is possible by this method. However, individual wells require individual treatment.

Another innovation is sustained-action acid, so-called because it receives an addition of an inhibiting chemical that reduces its rate of reaction, and so overtreatment at the face of the bore hole is prevented. The merit of this innovation appears to be vouched for by the fact that wells so treated decline in production at a slower rate than wells which have been conventionally acidized.

A Shot-Hole Recorder—R. B. Bossler, in OIL AND GAS JOURNAL, vol. 37 (1938), No. 7, pp. 44-45.

When a well has been shot with nitroglycerine the size and shape of the shot-hole, and the position and extent of the caves are matters of great interest to operators, especially in secondary recovery work where difficulty is experienced in setting packers and there is need of some device that would at least tell when the wall is bad.

To meet this need the author, after some experimenting devised an apparatus (which he describes and illustrates) that operates on the principle of a feeler or finger actuated by a spring that follows the contour of the well wall, and through a linkage acts on a variable resistance in an electric circuit. Variation in the resistance causes a variation in the current flowing, which is indicated on an ammeter. The number of fingers may be one, two, or three, and long enough to measure a hole up to 28 in. in diameter.

In operation, the outfit, which weighs 14 lb., is lowered into the hole with the fingers retracted. They are released when bottom is touched. The instrument is then slowly pulled up and readings are taken at intervals of about 6 to 12 in. The well may be dry or filled with fluid; in the latter case provision is made for insulation.

The instrument affords some useful information. The size of the shot-hole is disclosed; the presence of cavities of larger diameter than the length of the finger is indicated by a vertical line on the ammeter chart. Some clue is obtained as to the nature of shot cracks and fissures and where cracks are large enough to allow easy flow of gas or fluids. Most important is that a hint may be obtained as to the best place for a packer.

The shape of the hole gives an idea of the effect of the cleaning out; the heart-shaped profile seems to be the usual shape.

Time Drilling—George Weber, in OIL AND GAS JOURNAL, vol. 37 (1938), No. 8, pp. 38-39-44.

The use of time drilling, which has been employed for some time in the Permian Basin of West Texas and New Mexico, has found widespread application in the Cotton Valley field of Northern Louisiana. Time drilling means making a record of the time required to sink the hole through a certain footage, or number of minutes required to make a foot of hole. Naturally, the rate of drilling will be fast or slow according to whether a particular formation is soft or hard. When one or more wells have been time-drilled the records may be used for correlation purposes in the drilling of other wells in the same field. The Cotton Valley operators use it chiefly as a means of determining tops and markers as a guide to coring programs.

Accuracy and reliability of time drilling data depend on close observation of details, such as weight carried on the bit, rotary speed of the bit, pump pressure, mud gravity, etc. Account must be taken of the fact that a fresh bit works faster than a dull one. It is to be noted that while time drilling is undoubtedly of considerable value it does not afford an infallible index of the formation drilled; to obtain the best interpretations it is necessary to check with cuttings, and later with cores and Schlumberger logs.

West Texas Drilling-in Practices—M. Tucker, in OIL & GAS JOURNAL, vol. 37, (1938), No. 6, pp. 44-45.

Conditions in the Permian basin of West Texas and New Mexico are such that extra effort must be made to avoid mudding the face of the producing horizon. Prominent among the methods employed are drilling under pressure with oil as the circulating mediums, which avoids the use of mud. Another method which avoids the use of pressure is the reverse circulation or Beckman process, in which the oil is forced down the annular space between casing and drill stem and up and out through special holes in the rock bit. This method is favored because it allows a more accurate logging of the section.

In an effort to avoid the pressure control method, some interesting pioneer work has been done in the

northern portion of the basin by the use of pulverized limestones as drilling fluid. In this procedure, chalk or limestone is used as a mud forming solid in the drilling fluid, and the producing section drilled in the usual manner, recording the drilling-time at frequent intervals as an aid in formation logging. When total depth is reached, a small acid wash is used to clean the calcium carbonate mud from the formation face, and the well then heavily acidized or shot for completion. It is assumed that the hazards of clogging the low pressure and porous formation with heavy mud is eliminated by this plan, as the acid wash acts as a cleansing agent before well completion.

Any calcium carbonate material that will give the proper viscous and weight qualities to the fluid will be satisfactory. Pulverized limestone, marble, oyster shells, chalks, etc., may be used. It is sometimes necessary to add some sort of mud-forming solid, such as colloidal clays.

Very high initial productions as compared to offsetting wells using mud in the Fuhrman pool in Andrews County have indicated the worth of the calcareous circulating medium, and have stimulated the present extension of its use.

NATURAL GAS

Recent Improvements in Natural Gasoline Manufacture—H. H. Beeson, in REFINER, vol. 17, (1938), No. 7, pp. 330-334.

The process employed by the Sabine Valley Gasoline Company, operating in the East Texas field, is presented as an illustration of progress in natural gasoline production, especially as determined by the character of East Texas gas. This process is the vapor rectification process which consists essentially in compressing the wet gas and passing it into an ordinary fractionation column or stabilizer (some times called a hot column) where the gasoline is taken from a reboiler and gas is passed out at the top through coolers for condensing reflux. In order to recover a high percentage of butane it is necessary to operate at lower temperatures than in an ordinary vapor rectification plant. Boiling propane is used as the cooling agent instead of water. This will require compressing the overhead vapors from the recovery column to approximately 700 lb. pressure before passing through the reflux condensers. The reflux obtained will be expanded into the top of the column.

The advantage of this type of plant is the installation cost and the ease and economy of operation. The process in itself is quite simple and requires a minimum of attention from the operator. The cost is low because of the low water circulation and the low quantity of steam required. It is also an advantage to have high pressure residue gas available for the field where a saving is obtained in the smaller residue pipelines required.

Opportunities for Natural Gasoline—R. C. Alden, in REFINER, vol. 17 (1938), No. 7, pp. 335-339.

The author presents a survey of the problems to be solved if natural gasoline is to retain its usefulness and value in the market.

As he sees it, the most serious economic flaw of the natural gasoline industry is the lack of adequate storage facilities for the proper marketing of a product that has a seasonal demand. During the summer time the stocks of refinery gasoline are being depleted and prices are at their best, whereas it is precisely that time when stocks of natural gasoline accumulate and its price is low. The modern refinery, if it utilizes all the butanes-butenes formed in its cracking stills, can make a finished gasoline of 13-lb. vapor pressure; the upshot is that little market exists for butane in summer natural gasoline. On this oversupplied market the natural gasoline manufacturers, lacking storage facilities, are obliged to crowd still more butane. This condition boils down to the fact that through the medium of price reductions the natural gasoline producers are forcing their customers to take something they do not need.

On the other hand the relative quality of natural gasoline has deteriorated, in the sense that while during the past decade there have been very pronounced improvements in the volatility and octane number of refinery gasoline, during the same interval there has been little improvement in the quality of natural gasoline. This means that natural gasoline is worth relatively less as an ingredient of motor fuel than it was 10 years ago. In fact, due to an inevitable reduction of the vapor pressure of natural gasoline its anti-knock value has actually declined.

As a constructive suggestion for improving the summer market for natural gasoline it is proposed that renewed consideration be given to the removal of pentanes. This will make natural gasoline more desirable for blending in summer grades of motor fuel; the pentanes removed could be added to unprocessed natural gasoline going to storage for winter use.

Attack on the problem of improving the anti-knock qualities of natural gasoline could well be concentrated on the hexane plus fraction, which is chiefly responsible for the low octane rating and amounts to about one third of the total volume. In other words, it may become necessary for natural gasoline manufacturers to apply refinery methods, even to the employment of polymerization and reforming processes.

A long step toward arresting decline in the margin of anti-knock superiority over refinery gasoline will be gained by abandoning the old doctor sweetening process in favor of the copper sweeteners that are coming into general use.

Another point is that iso-pentane has come into great prominence as a blending agent in 100-octane aviation gasoline. The author finds a distinct possibility that the natural gasoline industry and its customers would both profit if iso-pentane, which is now largely lost among relatively inferior other constituents of natural gasoline, were segregated as a distinct commodity.

In the background there still looms the possibilities inherent in polymerization processes by which, it is stated, natural gas can be made to produce four times as much gasoline as is now obtained; these processes contemplate the ultimate conversion of methane and ethane, now relatively valueless, into liquid products. Somewhat nearer at hand are immense possibilities in the conversion of natural gas into industrial chemicals.

The author sounds a complaint that road and laboratory tests on knocking characteristics are annually made by various organizations on all conceivable varieties of motor fuel, except natural gasoline. The industry should see that its product is included in such studies.

TRANSPORTATION

Tankers as Naval Auxiliaries—B. Orchard Lisle, in U.S. NAVAL INSTITUTE PROCEEDINGS, vol. 64 (1938), No. 9, pp. 1249-1256.

Since modern navies are now on an oil-fuel basis, it is necessary that a fighting fleet be able to get full supplies at any time and in any place likely to be within its sphere of action. Well distributed land bases are only a partial answer because the exigencies of warfare may make the time factor of immediate and crucial importance.

Hence a navy will require the services of two principal types of oil tankers—a group of slow moving vessels to feed the storage bases and another group of speedy craft to keep up with the fighting ships ready to supply an instant need while the fleet is under way; perhaps the fast tanker will supersede all others for naval purposes. The author believes that it would be unwise to depend on privately built and owned vessels for this service; hence naval authorities must either build their own, or government must subsidize the construction of suitable craft that can be taken as required. Aside from indispensable special constructive features speed is of prime importance in military operations, and is not without importance in peace time employment. The author outlines various details of outfitting; the naval tankers should carry guns, and might on occasion be used as independent commerce raiders equipped with aircraft.

Pipeline Coatings and Cathodic Protection—Dave Harrell, in PETROLEUM ENGINEER, Vol. 9, (1938), No. 9, pp. 90, 92, 93.

A general answer to the question: What is the best coating to apply to a piece of pipe? is that the best coating is one that will possess the highest electrical resistance for the longest period of time. Another constantly recurring question is: How much current does it take to protect a pipeline? The answer to that question is that it depends on a great variety of circumstances. On the basis of the author's experience the minimum necessary voltage drop from soil to pipe is —0.24 volt. The choice of this minumum has followed from the practical observation that all local actions cease at this point and that iron is not taken into solution in any of the soils so far encountered; that is to say, no soil has been encountered in which the sustained iron-to-iron potential exceeded 0.24 volt. When this absolute voltage drop is assured any further action by galvanic currents from natural sources is averted. The amount of current to be fed to the line will naturally depend on a number of circumstances such as the area exposed, the resistivity of the soil, and last but apparently not least, on the condition of the coating on the pipe. If the coating is perfect no current at all would be drawn at the low voltages commonly employed in protecting pipelines. In fact, the amount of current that passes, in comparison with the amount of current necessary for protection of a bare line of similar area is a measure of the quality of the coating. As an example, the author's company has a mile of well-coated 18-in. line that requires only six amperes at six volts. On a similar section with a coating in bad condition 20 times as much current is needed.

All this points to the ultimate answer: make all pipe coatings as electrically resistant as possible. The ultimate test of an electrically resistant coating is a good holiday detector, which will not only detect actual pin holes but also spots where the coating is too thin. For such detective work it is necessary to use a spark capable of jumping an inch in dry air. Such a detector will find all weak spots.

REFINING

Solvent Extraction of Diesel Fuels—C. G. Dryer, J. A. Chenicek, Gustav Egloff and J. C. Morell, in INDUSTRIAL ENGINEERING CHEMISTRY, vol. 30 (1938), No. 7, pp. 813-821.

The rapid increase in the use of high-speed Diesel engines for automotive and locomotive as well as for stationary power has led to a large increase in the demand for suitable fuels. There has also been a tendency toward Diesel engines of lower horsepower, for it has been estimated that 90 percent of the installations in 1936 were engines of less than 100 h.p.

These smaller high-speed engines will require approximately an additional 7,500,000 bbl. of fuel on the basis of 4.5 bbl. per horsepower per year. Most of this additional fuel will necessarily be of higher ignition quality than that used for the large slow-speed engines because the high-speed engines operate under widely varying conditions of load and speed.

It is essential that large quantities of fuels of high ignition quality be available in order to ensure the continued development of the Diesel engine. Straight-run fuels produced from various crudes appear to have a sufficiently high cetane number to operate most high-speed engines. Cracked fuels, derived from crudes of various fields, however, have an average cetane number of 35 which is well below that recommended by the engine manufacturers. A fuel of sufficiently high ignition quality for most purposes probably can be made by blending straight-run and cracked fuels in the proper proportions. However, fuels for aircraft engines, besides having high ignition quality, must have other desirable properties such as low cloud and pour points. Straight-run fuels which have high ignition quality unfortunately have high pour points and consequently cannot be used at low temperatures such as those accompanying use in aircraft. Cracked fuels on the other hand, have low pour points but also low ignition quality.

Solvent extraction of cracked Diesel fuel from the Pennsylvania, mid-continent, Texas, and California fields produced raffinates of substantially improved ignition quality without appreciable change in physical properties of the fuels. Sulphur dioxide was more selective than furfural. The raffinates showed an improved response to a Diesel dope (acetone peroxide) over that of the original fuel. Addition of a pour point depressant to the raffinates caused the same lowering of pour points as addition to the untreated fuels. Thus it was possible to prepare fuels of high ignition quality from cracked stocks by solvent extraction, either alone or in conjunction with Diesel dopes, a pour point depressant, or both. Solvent extraction of straight-run fuels from the same four fields yielded raffinates with improved properties, but the increase in ignition quality was not as great as for the cracked fuels.

The extracted portions of the fuels had low aniline points and high blending values, which indicated they were essentially aromatic in character. They probably could be used as blending stocks for tractor fuels, cracking stocks for high-antiknock gasoline, or as solvents.

Extractions with furfural at lower temperatures indicate that these two solvents are only slightly more effective at lower temperatures than at room temperature.

Acid treatment of both cracked and straight-run fuels caused only a negligible increase in the Diesel index.

Cause of the Bleaching Action of Fullers Earth—E. Erdheim, A. Blankenberg and N. Zaharia, in PETROLEUM, vol. 34 (1938), No. 24, pp. 6-7.

The facts indicate that the decolorizing action of a bleaching clay depends on the formation of what is known to colorists as a lake, one component of which is a coloring substance in the product that is being bleached, and the other is one of the mineral components of the clay.

For instance, when shaken in a petroleum distillate a certain bleaching earth (Sondafin) acquired a fine violet color; when extracted with absolute alcohol the dried spent earth yielded a colored oil containing 1.30 percent of mineral ash, mostly iron, aluminum and silicon oxides; extraction of the powder with acetone yielded a colored oil with 3.65 percent of ash. Extraction of the original earth with these two solvents failed to dissolve any mineral matter at all.

The logical conclusion is that the clay contains a certain proportion of zeolitic material which has the ability to combine with coloring matters that dissolve in appropriate solvents. The clay also evidently contains other zeolitic constituents that form insoluble lakes, as after extraction with alcohol or acetone the spent earth used in these experiments still contained a blue-green color that could not be removed by any organic solvent. This insoluble color could be bleached by caustic alkali but reappeared unchanged on acidification.

CHEMISTRY

Mixed Polymerization of Butenes by a Solid Phosphoric Acid Catalyst—V. N. Ipatieff and R. E. Schaad, in PETROLEUM, vol. 34 (1938), No. 24, pp. 1-5.

Polymerization of isobutene, n-butenes and mixtures of isobutenes and n-butenes under 7.8 atmospheres pressure at 95 to 120 deg. or 170 deg. C. results in the production of polymers which contain 70 or 55, or 74 to 80 percent of octene; from these products there is obtained, by hydrogenation, octane with octane numbers from 83 to 100.

The polymers formed from mixtures of isobutenes and n-butenes under 48 atmos. pressure at 149 deg. C. contain 88 volume percent of octene, which yields a hydrogenized octane with an octane number of 95.

For preparation of octanes with high anti-knock value the polymerization of a mixture of isobutenes and n-butenes gives a better octane than mixing the separately prepared butene polymers. For instance, the octane number of an octane made by mixed polymerization of 50 percent isobutene, with subsequent hydrogenation of the latter, was 3.5 points higher than an octane mixture composed of 50 percent of hydrogenated di-n-butene and 50 percent of hydrogenated di-isobutene (iso-octane).

In this process the function of the phosphoric acid catalyzer is to esterify the olefines; the esters so formed subsequently decompose, the hydrocarbon radicals polymerize, and the phosphoric acid is regenerated.

Condensation of Olefines with Iso-Paraffins in Sulphuric Acid—S. F. Birch, A. E. Dunstan, F. A. Fidler, F. B. Pim and T. Tait, in OIL & GAS JOURNAL, vol. 37 (1938), No. 6, pp. 49-52-55-58.

At the present time we have the interesting situation where the engine designer has been outpaced by the chemist, who has made available automotive fuels that are too good for the engines now on the market. However, it is entirely possible that engines may soon be so improved that the demand for these super-fuels may exceed the supply and then the chemist will have to try to catch up again.

Among the super-fuels which the engine designers are not yet able to use to the best advantage are certain iso-paraffinic hydrocarbons and iso-propyl ether. The iso-propyl ether is very valuable as a blending agent, but it has a somewhat low calorific value. For this reason the iso-paraffinic hydracarbons which have a higher power output, are more attractive. Two of these hydrocarbons, iso-octane and an isomer obtained by hydrogenation of the butene-isobutene condensation product are now being produced on an industrial scale, and new plants in course of erection will add to the supply.

However, present methods of producing the iso-octanes involve hydrogenation, with its attendant disadvantages and comparatively high costs. If iso-octane could be produced by the direct combination of isobutane with iso-butene, for example, not only would such a reaction increase the potential supply of iso-octane but it would eliminate hydrogenation and at the same time find a use for isobutane, which at the present time has little more than fuel value. By using catalysts, Ipatieff and others have succeeded in reacting isobutane and isobutene, but the reaction product has a wide boiling range and is obviously complex in character.

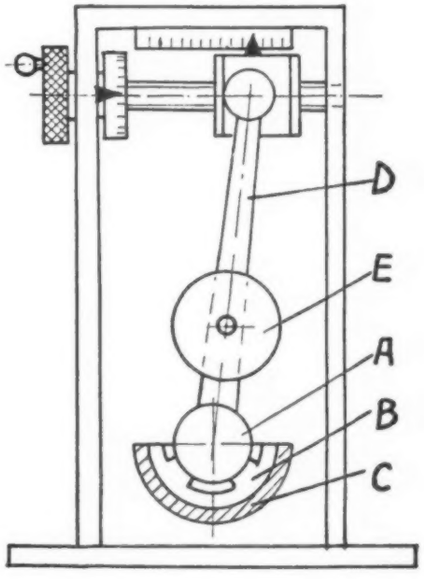
The authors confess themselves astonished to find how easy it is to effect this reaction under surprisingly mild conditions. They find that isobutane and isobutene react readily at ordinary temperatures in the presence of sulphuric acid (97 percent) to give a product consisting essentially of isoparaffins of high octane rating and containing a high proportion of iso-octanes. The procedure is simple: isobutane and sulphuric acid are placed in a suitable vessel supplied with a stirrer, and isobutene is run in during a period of 90 minutes, the temperature being kept at 20 deg. C. by circulating cold kerosene through a coil. The product is then freed from acid and distilled. The fraction boiling up to 185 deg. C. has an octane number of 90 and the yield is 140 percent based on the olefine taken. This yield is practically double that obtained by hydrogenation of the reaction product of butene-isobutene and isobutane.

PHYSICS

New Physical-Chemical Viewpoints on the Lubrication of Bearings—H. Burstin, in PETROLEUM, vol. 34 (1938), No. 23, pp. 1-9.

The author reviews the modern theory of polarity or molecular film theory of lubricating oils and the methods of testing oils based on this theory, but reaches the conclusion that actual experience in a testing machine is still the best means of comparing lubricating oils. However, figures obtained on one mechanical testing machine are valid only for that machine and do not necessarily correspond to figures obtained on another machine. Absolute figures need be looked for only from some process that gives a physical basis for measuring the coefficient of static friction between two lubricated surfaces.

An apparatus that seems to have much promise for measuring the static friction of oils is the Wilder Friktometer, which is diagramattically represented in the accompanying sketch. This apparatus con-



sists of a specially ground and polished shaft, **A**, of hardened steel which rests on two specially formed bronze bearings, **B**, or some other metal. These bearings have two supporting surfaces, each having an area of one square millimeter. These surfaces are carefully polished to a cylindrical surface accurately conforming to the surface of **A**. To the shaft **A** is clamped a lever arm, **D**, on which is hung a weight **E** to produce a certain load on the bearing surfaces. The upper end of the lever **D** is a spherical knob which can be displaced laterally by means of a micrometer screw.

In operation, the saucer **C** is filled with the oil to be tested, or the two bearing surfaces may be simply moistened with the oil. The lever **D** having been brought to the vertical position, it is displaced to the right or left by the micrometer screw until the center of gravity of the system has been moved far enough to overcome the moment of inertia of the static friction. The lever then topples over. The point of toppling is accurately registered by the micrometer.

Great accuracy and reproducibility is ascribed to this instrument. (See also following abstract).

Determination of Friction Coefficients with the Wilder Friktometer, H. Burstin and E. Katz, in PETROLEUM, vol. 34 (1938) No. 23, pp. 10-11. (See also preceding abstract).

The reliability of the results obtained with the Wilder Friktometer depends in the first place on the uniformity of the bearing surface; this surface being quite small, even minute irregularities have a large influence on the friction coefficient of the oil under test. The necessary uniformity of surface is a matter of careful polishing.

When properly done, the tests show a range of variation of less than two percent, which means that the average error is less than plus or minus one percent.

After the instrument had been put in order and its reliability proved, it was used to study the process of selective refining and deparaffining of lubricating oils of different origins by the cresol extraction process. It was found that the rise of the viscosity index and aniline point of the oil at each stage of the extraction process is paralleled by a rise in the friction co-efficient. The deparaffined fourth extract showed the highest coefficient.

The investigation was further extended to a study of various polar compounds that are known to increase the lubricity and diminish the frictional resistance of lubricating oils. The test oil was a sulphuric acid refined naphthenic auto oil with Engler viscosity 25 deg. at 50 deg. C., V. I. 28 and a cold point of 180 deg. C. The accompanying table shows the figures obtained: in some cases the wetting coefficient was also determined.

	Friction Coefficient	Wetting Number
Original Oil	0.221	21.8
0.05 Percent high Molecular	...	...
Sulphur-containing hydrocarbon	0.219	21.1
0.05 Percent Naphthenic acid methyl ester	0.218	26.5
0.05 Percent Condensation product of Chlorinated paraffin	0.214	...
0.32 Percent Lead Stearate	0.213	...
0.05 Percent Chlorinated Paraffin	0.212	...
0.01 Percent Oxidized Paraffin	0.209	28.0
0.05 Percent Naphthenic acid	0.207	26.0
0.05 Percent High pressure dope A	0.204	30.3
0.05 Percent Elain	0.204	...
5.00 Percent High pressure dope B	0.203	30.9

From this exhibit it is seen that the well-known lubrication promoting action of polar compounds finds an expression in a lowering of the friction coefficient. More or less parallel herewith is an increase in the wetting number of the oil, although here some breaks appear.

A New Viscosity Temperature Chart with Indicator for the Viscosity Pole-Height and Strike-Constant—Ubbelohde and Kemmler, in OEL UND KOHLE, vol. 14 (1938), No. 26, pp. 541-544.

The new chart is the same as that contained in Ubbelohde's book "Zur Viscosimetrie," with the addition of two guides for simplifying the graphical methods for finding the desired values.

The basic values are viscosity of the oil at a given temperature, the viscosity at any other temperature, the direction or strike constant of the viscosity straight line, and the viscosity pole-height. Given any two of these, the others can be calculated. The authors give directions for using the new chart.

(Note: Ubbelohde, who has made important contributions to the measurement of viscosity in absolute units, condemns the current concept of viscosity-index as having only an empirical basis, and recommends its substitution by the viscosity pole-height.—Ed.).

USES

Corrosion by Diesel Fuels—Th. Hammerich, in OEL UND KOHLE, vol. 14 (1938), No. 26, pp. 539-541.

The probable corrosiveness of oils on the metallic parts of machinery can be recognized by the usual routine tests for acidity, presence of creosotes, etc., but zinc presents a special csse. Some oils which appear to be harmless in most cases will corrode zinc. A circumstance which may become of importance is that if the oil comes into contact with the zinc lining of galvanized drums, pipes, etc., zinc oxide will then be separated in the combustion chambers of Diesel engines, leading to stoppages or incrustation of the injection sprays and producing other inconveniences.

This circumstance therefore calls for a special test for the corrosiveness of Diesel oils on zinc. This is made by hanging well cleaned and weighed strips of metallic zinc in samples of the oil at 50, 75, and 100 deg. C. for 7, 14, 28, and 56 days. The zinc oxide that has formed is rubbed off and the extent of corrosion (loss of weight) is determined by again weighing the strip. Experiment showed that a short test—24 hours at 100 deg. C.—is sufficient to indicate what is to be expected in the case of prolonged contact at ordinary temperatures.

The author applied the test to a wide variety of Diesel oils and found most of them non-corrosive on zinc. Exceptions are certain Texas and particularly Roumanian oils. Some synthetic and coal distillate oils corrode zinc.

Behavior of Diesel Fuel at Low Temperature—L. Rosenfeld, in PETROLEUM TIMES, vol. 39 (1938), Nos. 1008 and 1009.

A principle of the Diesel engine is that the compression ratio at which the fuel will be ignited must rise as the temperature of the air in the cylinder at the beginning of the stroke is lowered.

Previous work with the C.F.R. engine on the relation between ignition and initial temperature of starting appears to have been limited to ordinary air temperatures (100 deg. to 70 deg. F. or 37.8 deg. to 21 deg. C.).

The author has extended this temperature range down to 22 deg. F.; for this purpose he used six Russian crude oils of very low pour points, below 58 deg. F. The results showed that the cetene value of a Diesel fuel gives no information as to the ignition qualities of the fuel under changed temperature conditions. One oil with a cetene value of 65.5 proved more difficult to ignite at this temperature than an oil with a cetene value of 58. One oil could not be ignited at all under the conditions of this test. This refractory fuel was the most dense (sp. gr. 0.879) and had the highest flash point (187 deg. F.) of any of the six oils; its cetene number was not ascertained.

Where the outside air is at extremely low temperatures, the temperature of the cylinder walls (cooling water) is of importance, and the required temperature varies with the nature of the oil. Thus, at 22 deg. F. the temperature of the cooling water had to be at least 77 deg. F. in order to secure ignition, whereas with another oil the minimum temperature was 122 deg. F.

Another point is that at low temperature the oil filter will clog. This may be avoided by having the filter close to the engine, or by using an oil absolutely free from impurities.

SUBSTITUTES

Substitute Fuels in 1937; A World Survey—Editorial, PETROLEUM TIMES, Vol. 40 (1938), No. 1017, pp. 47-50.

From a variety of sources data on the consumption of motor fuels and their substitutes in European countries are condensed in the following table.

In countries outside of Europe it is noted that in the United States the use of benzole represents about 0.6 percent of the motor fuel consumption of that country. In the Philippines the production of alcohol fuel from molasses in 1937 amounted to 20 percent of total requirements. In Cuba the proportion was less than four percent. In Australia substitute fuels were represented by 2,300 tons of alcohol and about 10,000 tons of benzole in a total consumption of over 1,000,000 tons. South Africa produced some 6,000 tons of molasses alcohol and consumed 1,600 tons of benzole together with about an equal amount of shale (torbanite) gasoline; total consumption of motor fuel was over 500,000 tons.

The total consumption of light motor fuel in Japan and Manchukuo was about 1,200,000 tons, of which 15,000 tons was distilled from Fushun shale and some 40,000 tons was benzole.

Such consumption of substitute motor fuels as now exists is the result of heavy subsidies and exemption from taxation, especially in the case of power alcohol.

European Proportions of Substitute Fuels, 1937

Country	Alcohol	Benzole	Oil from Coal Synthetic gasoline	L.T.C. gasoline	Shale spirit	Total substitutes	Total light motor fuel consumption	Percent substitutes
	In metric tons							
Germany	210,000	430,000	800,000	*	—	1,440,000	2,640,000	54.5
Esthonia	—	—	—	—	7,300	7,300	14,300	51.0
Czechoslovakia	50,600	12,000	—	—	—	62,600	220,000	28.5
Lithuania	1,294	—	—	—	—	1,294	5,700	22.7
Hungary	10,516	3,100	—	—	—	13,616	69,100	19.7
Poland	7,955	10,000	—	—	—	17,955	98,200	18.3
Latvia	2,154	—	—	—	1,300	3,454	19,400	17.8
Jugoslavia	3,806	—	—	—	—	3,806	30,200	12.6
Belgium	—	36,700	—	—	—	36,700	408,800	9.0
France	153,400	80,000	13,000	—	1,500	247,900	2,827,000	8.8
United Kingdom	16,000	230,000	116,000	4,000	26,000	392,000	4,840,000	8.1
Italy	37,000	—	—	—	—	37,000	483,500	7.7
Austria	2,300	8,200	—	—	—	10,500	146,300	7.2
Sweden	15,247	500	—	—	—	15,747	503,200	3.1
Holland	—	10,800	—	—	—	10,800	392,600	2.8
Finland	—	200	—	—	2,700	2,900	112,500	2.6
Switzerland	50	3,000	—	—	—	3,050	203,900	1.5
Total	510,322	824,500	929,000	4,000	38,800	2,306,622	13,014,700	17.7

Total European light motor fuel consumption including countries not enumerated above ..... 14,344,000 metric tons

*Included under synthetic gasoline.

Motor Fuels from Cracking Shale Oil—G. Egloff, J. C. Morrell and G. B. Zimmermann, before INTERNATIONAL SHALE OIL CONFERENCE, Glasgow, June, 1938.

This paper describes application of the modern cracking process to shale oils from various parts of the globe. The operations were conducted on a pilot plant scale. The oils tested were from France, Manchukuo, Australia, Esthonia, South Africa, Sweden, and Spain.

The general results show that the modern cracking process is adaptable to processing shale oil in about the same manner as in the case of crude petroleums. The yields of gasoline, however, are somewhat lower. Further, there are more tar acids and tar bases to contend with; these substances make it necessary to take precautions against corrosion and cause relatively high losses in treating the various fractions. On the other hand these tar compounds are a source of valuable chemical by-products.

ECONOMICS

Cost of Oil Production—G. R. Hopkins and K. L. Stone, in OIL AND GAS JOURNAL, vol. 37 (1938), No. 9, pp. 15-17-85.

This article, prepared by two government economists, opens with the statement that the average cost of producing crude oil in the United States in 1937 was about $0.85 per bbl.; the average at present writing (June 1938) is probably a cent or two higher.

The authors observed that these figures may be of value when considered with the estimated average price of $1.20 but, as usual with the averages of widely diversified results, they conceal much; for instance, they do not show that in 1937 many wells were operated at a heavy loss, especially stripper wells in the eastern states, the operators of which appear to be losing upwards of a dollar on every barrel produced. These operators are evidently ignoring depletion, depreciation, and all other intangibles. Stripper operators in the Mid-Continent are not so badly off, while producers in the Louisiana Gulf Coast and Central Kansas showed large indicated profits in 1937.

For the purposes of this analysis three districts were selected: Kansas, because it typifies the mixed stripper and flush prorated production of the Mid-Continent; the Louisiana Gulf because it has by far the largest production per well per day of any district; and West Virginia, because all its wells can be classed as strippers. The gist of the findings are contained in the accompanying table.

Period—	Net Cost	Average selling price
KANSAS:		
1927-1930	1.390	1.390
1931	1.158	.668
1932	1.015	.914
First nine months of 1933	.879	.545
Last three months of 1933	.950	1.029
1933	.894	.665
1934	.882	1.031
1937	.970	1.230
LOUISIANA GULF COAST:		
1931	.035	.653
1932	.696	.835
First nine months of 1933	.634	.540
Last three months of 1933	.727	.988
1933	.659	.665
1934	.753	.990
1937	.705	1.150
WEST VIRGINIA:		
1927-1930	2.210	3.160
1931	2.168	1.575
1932	2.130	1.572
First nine months of 1933	2.006	1.384
Last three months of 1933	2.142	2.113
1933	2.041	1.571
1934	2.113	2.089
1937	2.300	2.280

It is true that company costs vary widely, depending on the nature of the business and the accounting methods used, but the authors consider the estimates for the 1937 averages as substantially correct, as they are supported by official compilations of prior years.

Considered in detail the figures indicate that the average small stripper operator in Kansas is losing money if he produces less than one barrel a day, that only a handful of wells in Louisiana Gulf Coast were operated at a loss in 1937, while in West Virginia, where only about 500 wells out of nearly 19,000 produce more than one barrel a day and where the average daily production is only 0.6 bbl., it is difficult to see any real profit.

Coal and Oil in the Trade Cycle—Oskar Tokayer, in PETROLEUM PRESS SERVICE, vol. 5 (1938), No. 28, pp. 325-328.

It has become almost a habit to attribute the slow growth of coal consumption in the post-war years to the competition of oil, the output of which has trebled during the same period. This view is particularly common in Great Britain, where the coal industry, once so flourishing, has sunk to the position of a depressed industry.

While it is undeniable that in some lines oil has displaced coal, an analysis of the facts shows that the losses of the coal industry cannot be wholly accounted for by the increase of oil consumption. It is estimated that, at the most, the displacement of British coal by oil cannot be more than 8,000,000 tons a year, whereas total consumption of British coal now registers an apparently permanent decline of 45,000,000 tons annually.

The inroads of oil as against coal in shipping have attracted most attention. Next is the Diesel railcar, which is making headway on the railroads, and the great growth in road transport, which is supposed to account for a lessened demand for coal by the railroads. It is true that automotive transport represents a shift away from coal consumption, but against this must be placed a large credit for the coal consumed by the motor industry itself. And on the other hand it is not to be forgotten that coal has largely appropriated to itself a formerly important market for oil products; not so long ago the oil industry existed mainly to supply kerosene for lighting purposes, which function has now been largely taken over by gas and electricity produced directly or indirectly from coal. In this connection the development of hydroelectric power is also not to be overlooked.

However, after all accounts are added up, the decrease in coal consumption cannot be wholly accounted for by the inroads of competition from oil or hydro-electric power. The real cause is apparently a decided increase in the efficiency of coal-using industries. For instance, since 1913 the amount of coal needed to make a ton of steel has fallen from 4 to 1¼ tons. The average number of units of electricity generated from one ton of coal is nearly 2½ times as great as in 1920. In fact, over 90 percent of the decline in the consumption of coal in the United Kingdom is accounted for by a smaller demand from blast furnaces, steel works and from the collieries themselves. Similar conditions must obtain in other coal markets. Nor is it to be forgotten that the ships that still burn coal are now far more efficiently operated than in the pre-war days.

The conclusion that emerges from these considerations is that technical factors working over a lengthy period of time have substantially modified the relative market positions of coal and oil, to the advantage of the latter, and the influence of these factors seems likely to continue in the future. Ignoring the short-term cyclical fluctuations of consumption, it may be expected, with a high degree of probability, that the demand for petroleum will continue to increase and that the demand for solid fuels will lag behind, at least in the older markets.

This should provide an incentive for the coal industry to do all in its power to improve its organization and technical efficiency, and to open new markets for its products.

The Oil Groups in 1937—Oskar Tokayer, in PETROLEUM PRESS SERVICE, Vol. 5 (1938), No. 24, pp. 277-280.

Despite the continued existence of tariffs, quotas, exchange restrictions and other impediments to the flow of world trade, and notwithstanding the hostile attitude of certain Governments, 1937 was the best year the oil companies have had since the last depression. In several cases, indeed, net earnings were higher than in 1929. With the wheels of industry turning more rapidly, with earnings consequently increasing and all forms of transport making further headway, sales of petroleum products showed a further marked improvement. Moreover, the major oil companies benefited last year from the decision taken by numerous Governments to augment their stocks of mineral oils with a view to decreasing their dependence on current purchases from abroad in time of war. In consequence of these favorable factors, world markets absorbed over eight percent more oil in 1937 than in 1936. According to estimates in the Royal Dutch Report, the world's total consumption of petroleum products (including substitutes) amounted to over 255,000,000 tons last year, against 236,000,000 in 1936.

The effect of this situation on the operations of the six principal oil companies is shown in the accompanying tables that exhibit their gross crude oil production and net earnings.

Although all the companies show steadily increased earnings since 1933, their earnings are still small relatively to 1929, considering the depreciation of currency values. Royal Dutch, Shell Transport, and Standard Oil (Calif.) are below their 1929 peak. During the past decade Standard Oil (N. J.) has earned an average of $66,000,000 a year, which is six percent of capital and consolidated surplus.

Gross Crude Oil Production (000's Omitted)

	Standard Oil (N.J.) (Barrels)	Royal-Dutch Shell (Metr. Tons)	Anglo-Iranian*‡ (Long Tons)	Socony-Vacuum (Barrels)	Texas Corpn. (Barrels)	Stand. Oil of Calif. (Barrels)§
1929	101,100	25,184	5,460	†	50,410	51,534
1933	156,231	21,953	7,086	32,731§	35,748	36,012
1934	179,336	24,078	7,537	35,081§	36,196	37,616
1935	193,503	26,620	7,487	37,958§	45,706	44,539
1936	206,356	28,480	8,198	59,625	53,854	43,062
1937	237,072	31,986	10,167	73,588	60,476	48,147

* Production from Iran only. †Company did not yet exist in its present form. ‡Net production. § Production in U.S. only.

Net Earnings (000's Omitted)

	Standard Oil (N.J.) $	Royal Dutch Fl.	Shell Transport £	Anglo-Iranian £	Socony-Vacuum $	Texas Corp. $	Stand. Oil of Calif. $
1929	127,922	126,471	6,765	5,206	*	48,318	46,633
1933	25,084	30,546	3,041	2,643	22,545	491†	7,560
1934	45,618	38,131	3,807	3,183	24,121	5,545	18,949
1935	62,863	54,279	5,021	3,519	22,525	17,065	18,594
1936	97,774	84,866	5,983	6,123	42,909	38,260	23,310
1937	147,993	87,617	6,616	7,455	56,808	54,574	41,254

*Company did not yet exist in its present form. †Loss.

World Production of Motor Cars—LEAGUE OF NATIONS MONTHLY BULLETIN OF STATISTICS, June, 1938.

The statistical year book of the League of Nations, 1937-38, which is shortly to appear, will contain the following table on motor car production. It is noted that official statistics are available only for the United States, Canada, Germany, and the U.S.S.R. For several European countries the available estimates vary greatly. (In this table 000's are omitted).

COUNTRY	1934	1935	1936	1937
AMERICA	2,870	4,120	4,616	5,017
CANADA	117	173	162	207
Passenger cars	92	140	131	153
Lorries, omnibuses, etc.	25	33	31	54
U.S.A.	2,753	3,947	4,454	4,810
Passenger cars	2,178	3,252	3,670	3,916
Lorries, omnibuses, etc.	575	695	784	894
ASIA				
Japan	3	7	10	10
U.S.S.R.	72	97	137	200
Passenger cars	17	19	4	18
Lorries, omnibuses, etc.	55	78	133	182
EUROPE (excl. U.S.S.R).	777	893	1,060	1,109
GERMANY	172	245	302	327
Passenger cars	145	204	244	264
Lorries, omnibuses, etc.	27	41	58	63
AUSTRIA	2	3	6	6
Passenger cars	2	2	5	5
Lorries, omnibuses, etc.	—	1	1	1
BELGIUM	1	1	1	1
Passenger cars	1	—	—	—
Lorries, omnibuses, etc.	—	—	—	—
FRANCE	187	166	203	200
Passenger cars	164	146	180	177
Lorries, omnibuses, etc.	23	20	23	23
ITALY	46	48	48	57
Passenger cars	41	41	36	43
Lorries, omnibuses, etc.	5	7	12	14
UNITED KINGDOM	355	417	481	493
Passenger cars	266	325	367	379
Lorries, omnibuses, etc.	89	92	114	114
SWEDEN	3	3	4	7
CZECHOSLOVAKIA	9	8	11	14
Passenger cars	8	7	10	12
Lorries, omnibuses, etc.	1	1	1	2
OTHER COUNTRIES	2	2	4	4
WORLD TOTAL	3,722	5,117	5,823	6,336

The figures given represent, as far as possible, national production, including exports of spare parts assembled abroad; vehicles assembled from imported spare parts have been excluded, as far as possible, from the production figures of importing countries.

The division between passenger cars and lorries, omnibuses, etc., is in many cases very approximate. The latter group generally includes ambulances, motor-hearses, street sweepers, fire apparatus, etc., but excludes tractors. The production of tractors in recent years in the U.S.A., the U.S.S.R. and Germany has been as follows (000's omitted):

	1934	1935	1936	1937
U. S. A.	....	161	227	....
U.S.S.R.	94	114	116	....
Germany	5.0	8.5	12.9	16.8

Trends in Civil Aviation—Oskar Tokayer, in PETROLEUM PRESS SERVICE, vol. 5 (1938), No. 23, pp. 265-268.

A study of the statistics of international air traffic indicates that it is almost depression proof. Even during the years 1929-1933 route mileage increased from 125,800 miles to 200,300 miles, while actual mileage flown rose from 53,379,000 to 100,580,000. Since the developments have followed at a still more rapid rate; at the end of 1937 regular air services covered a route mileage of 300,000 miles and actual mileage flown in that year amounted to about 200,000,000.

This expansion is undoubtedly due in large part to the obvious advantages of air transportation for certain services, although of course, improvements in operating efficiency have helped greatly, especially in the international sphere. Here there is a distinct trend toward non-stop long-distance flights between remote centers, and many short routes are being abandoned.

Concurrently with this development there has been a shift from national toward international operations, and more co-operation between individual companies, which has led to the disappearance of smaller concerns which could not exist under the changed conditions. However, judging from the annual reports of the separate companies, the extension of domestic routes appears to have reached its limit, though there has been a further increase in the length of international lines.

The accompanying table gives figures relating to several of the more important countries for 1937.

Commercial Air Transport in 1937

	Distance Flown (Thousand Klms.)	Passengers Carried	Freight (Metric Tons)	Mail Tons)
U.S.A.	123,194	1,267,580	4,047	*
Germany	18,000	326,000	4,900	3,800
France (1)	10,505	89,076	1,217	437
Great Britain (2)	10,355	85,741	177†	1,134
Holland	8,472	120,577	1,675	663
Italy (3)	7,970	75,458	569	385
Belgium	2,414	‡	185	115
Sweden	2,352	41,126	386	568
Switzerland (4)	1,415	31,344	196	155
Czechoslovakia (5)	893	13,462	140	24
Australia	795	19,501	160	81

(1) Air France only. (2) Imperial Airways and British Airways only. (3) Ala Littoria only, year ending 30th June. (4) Swissair only. (5) C.L.S. only. * Included in freight. † British Airways only. ‡ Not available.

Several other trends may be noticed. More and more countries are applying ordinary postal rates to all mail. Another is that since the introduction of faster machines and larger pay-load capacity, air transportation is gradually approaching self-support; this is, shown by the fact that several important countries have found it possible to reduce government subsidies to aviation, especially in international air traffic.

At the same time, in view of the substantial number of companies operating, it is surprising that the number of aircraft with which world air traffic is now being operated should be so small. According to the latest publication of the British Air Ministry, commercial machines total 1,832, compared with 17,818 sporting and private aircraft in use in the world. Of these commercial aircraft, 444 were in the British Empire, and 311 in the United States. Of European continental countries, France accounted for 173, Germany 151, Italy 108, Holland 46, and Poland 41.

Fresh Decline in Roumania's Oil Industry—Oskar Tokayer, in PETROLEUM PRESS SERVICE, vol. 5 (1938), No. 32, pp. 375-377.

Roumania has in recent years dropped from fourth to sixth place among the world's oil producers and both the oil men and especially the fiscal department of the government are seriously disturbed. An indication of this decrease is given by the following figures, relating to the January-June statistics of the three years named:

	1938	1937	1936
Crude output, tons	3,330,500	3,654,700	4,352,150
Refinery throughput, tons	3,027,260	3,417,990	3,956,660
Drilling (meters)	161,890	208,500	165,160

The contraction in crude oil production since 1936 is about 23.4 percent. Drilling operations increased by 26.2 percent in 1937, but in 1938 lost all and more of this gain.

The decline in crude production is, on the one hand, attributable to the rapid exhaustion of the Dambovitza field, though this was partly offset by the increased production in older fields as a result of deeper drilling. On the other hand, the operators are conspicuously refraining from new large-scale drilling on previously unexploited oil fields, and they show few signs of adopting aggressive programs in the immediate future. Meanwhile the known reserves continue to diminish.

Roumania's export capacity is therefore weakened, not only by declining production but also by increased domestic consumption, which has risen from 707,800 tons in the first half of 1936 to 809,570 tons in 1938. Further increases in domestic requirements are expected, which under present conditions will be at the expense of the export trade.

Representatives of the oil industry in Roumania ascribe the decline to the damper on enterprise imposed by the legal and other restrictions maintained by the government, and they say that the outcome of the crisis through which the industry is passing will depend on what the government does to assist the industry's operations. The government most likely will do something because it can ill afford to lose its revenue from oil. The recently appointed Supreme Economic Council is earnestly studying the matter.

The Motor Industry in the Trade Cycle—Oskar Tokayer, in PETROLEUM PRESS SERVICE, vol. 5 (1938), No. 32, pp. 373-375.

The United States motor manufacturers have felt the full impact of the depression which has raged during the past twelve months. Indeed, the decline in the activity of the motor industry has been more severe than that suffered by the economy as a whole, while it has scarcely begun to share in the recovery which has lately been evident in certain other trades. The point may be illustrated with the aid of a few figures. The following indices of business activity in general (adjusted for seasonal variations) are those of the Federal Reserve Board (1923/5 = 100):

	June, 1938	June, 1937
Industrial Production	77	114
Construction Contracts	54	61
Factory Employment	76.1	101.4
Freight Car Loadings	58	78

An early and sustained improvement in automobile sales would not only benefit the motor industry, which has been so severely hit by the trade depression, but would give a powerful fillip to general economic activity. No less than $1,500 millions have been invested in the American automobile industry, which now employs directly and indirectly, more than 6,000,000 men. The following table gives some idea of the vast quantities of materials absorbed by the motor industry of the United States every year:—

	Total Consumption in U.S.A.	Consumption in Automobile Industry	Percent of Total
Steel (thousand tons)	32,692	6,554	20
Malleable Iron (tons)	688,000	371,500	54
Crude Rubber (tons)	543,000	434,400	80
Plate Glass (thousand square feet)	213,161	154,961	73
Lead (tons)	681,700	214,300	31
Gasoline (million gallons)	21,346	19,218	90
Anti-freezing Compounds (thousand gallons)	35,500	35,500	100

The latest issue of AUTOMOBILE FACTS AND FIGURES—the annual publication of the American Motor Manufacturers' Association—shows that 25,000 road transport users in that country possess an aggregate of no less than 900,000 vehicles. The most important owners are the state and local authorities with a total of 222,780 at the end of 1937; commercial transport concerns possess 156,945 vehicles and there are 85,558 tank-cars used in the transportation of mineral oils. Another indication of progress in this sphere is the growth in the use of trailers—including caravans, which have opened up new possibilities for motors on tour. The number of trailers in use rose from 262,507 in 1930 to 1,019,985 in 1937. Again, the motor omnibus is now widely used for the conveyance of children to and from school, the number of such vehicles in use amounting to the surprising total of 84,000 at the beginning of this year.

Economic Aspects of Polymerization—M. B. Cooke, in REFINER, vol. 17 (1938), No. 7, pp. 325-329.

Interest in the production of high-octane aviation gasoline has caused a number of refineries to install poly plants to operate by one or another of the patented processes that are on the market, as it were. Some of these installations have been highly profita-

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ble, others not so profitable. When this difference in success is analyzed it is found to be related to the matters of new equipment required and nature of the charging stock that is available. If, for example, a refiner does not have an efficient high-pressure gas-recovery plant and wants to make polymer gasoline, he is faced with an outlay for the gas-gasoline recovery plant which is the major cost in the installation of a polymerization plant. With such a plant already existing there is little new equipment required beyond a furnace, a reaction coil and a fractionating tower.

The first problem to be solved by a prospective purchaser of a polymerization plant is one of charge stock. For good yields the present polymerization plants require a charge stock having at least three carbons, propane-propylene, to the molecule, but they do not convert gases of one carbon atom and only partially those of two carbon atoms to the molecule. Higher yields of distillate are obtained from a C_4 charge stock, butane-turylene, than from any other lighter stock. It is considered uneconomic at present to install a polymerization plant unless at least 1,500 bbl. of charge stock containing at least 75 percent of C_3 and C_4 compounds are available daily.

Assuming that the matter of cost of equipment has been largely absorbed in pre-existing or otherwise necessary equipment for cracking and reforming, the installation of a polymer gasoline plant will almost always be justified.

RESEARCH

A New Principle of Lubrication: Chemical Treating of Bearing Surfaces—A. L. Foster in NATIONAL PETROLEUM NEWS, June 29 (1938). pp. 25-28.

It is stated that chemists and metallurgists of the Standard Oil Co. (Calif.) have developed a method known as the Feritex process by which steel bearings are treated with certain chemicals in such a way that certain constitutents of the steel, such as ferrite, will be selectively etched out. The surface of the metal is thus covered with a network of microscopic grooves, slits or pits while still preserving the even level of the main portion of the finished and polished surface.

This innovation is credited with two favorable results. In the first place the ferrite grains dislodged from the surface by the treatment are the ones which are most likely to be torn from their places and carried between the rubbing surfaces, which they scratch and wear. In the second place, the shallow depressions left by the etching treatment are filled by the lubricant, which is thus given a much better toe hold on the bearing. The lubricated surface so produced has strong extreme pressure properties, carrying high loads without failure. Tested on extreme pressure machines, Feritex-treated rings lubricated with straight mineral oils are said to show a film strength or load carrying capacity six times that of untreated rings and a reduction of wear of 20 to 1.

A particular advantage is seen in a marked reduction of the break-in period of new Diesel engines from 100 to three hours, which in subsequent use is conducive to low cylinder and ring wear.

ASPHALT & TAR

Influence of Paraffin on the Characteristics of Bitumens—Part II—Vasile Th. Cerchez and Virgil Niculescu, in MONITEUR PETROLE ROUMAINE, vol. 39 (1938), No. 12, pp. 989-993.

In a previous work the current opinions and theories on the effect of paraffin on the properties of asphaltic and bituminous road materials were reviewed. In the present work the subject is studied experimentally.

In this study, use was made of three paraffinous substances namely: a commercial paraffin with a drop point of 52.50 C.; a commercial ceresin, drop point 85.5 deg. C.; and a pipeline wax, drop point 83 deg. C. These three substances were each mixed at the rates of 1, 3, and 5 percent with each of five bitumens of various degrees of hardness, and the properties of the mixtures were investigated.

In all mixtures with the commercial paraffin (drop point 52.5 deg. C.) the plastic range was diminished in proportion to the amount of paraffin added, and in proportion to the softness (ring and ball method) of the original bitumen. In the case of the ceresin additions, the plastic range increased in porportion to the percentage of ceresin, but the increase was the smaller the softer the original bitumen. In the mixtures with pipeline wax the plastic range was also increased in some cases but not in others; here the changes were more markedly dependent on the original softness. These preliminary results were subsequently confirmed by experiments on a larger number of samples.

The conclusion is that ordinary paraffin reduces the plastic of bitumens range proportionally to the amount added; ceresin increases it markedly in hard but less in soft bitumens, while pipline wax increases it in some cases, diminishes it in others and in still others leaves it unchanged.

BOOKS

Oil and Petroleum Year Book 1938, published 1938 by WALTER E. SKINNER, London; 382 pages, 11S.

The 29th volume of Skinner's contains details regarding 774 British and foreign companies, their histories, dircetorates, accounts, dividends, etc. These companies include producers, refiners, distributors, dealers, finance companies, shippers. Lists are given of 2,733 directors, 365 secretaries, 272 consulting engineers, etc. Much information of interest to investors in oil securities is included. Oil production statistics are shown by countries as well as by leading British companies. The compiler has included a list of 724 trade names of petroleum products and a glossary of technical terms used in the petroleum industry. An extensive list of manufacturers of machinery and oilfield equipment is given.

For the limited field covered, this volume makes an excellent reference book.

Driller's Wire Rope Handbook—Published 1938 by BRODERICK AND BASCOM ROPE CO., St. Louis, 79 pages.

Although primarily a trade publication this booklet contains much systematized information on wire ropes, their construction, uses, care, and manipulation in the various operations in which wire ropes are employed in the petroleum industry (and they are many). It can be recommended as a manual to be consulted by drillers and engineers.

Diesel Engine Catalog—Vol. 3 (1938), edited by B. J. von Bongart and Paul H. Wilkinson; Published by REX W. WADMAN and distributed by DIESEL ENGINES, INC., New York, 287 pages.

This book is intended to supply a cross section of the Diesel industry. The engines built by many firms are described and illustrated. The new designs developed during the past 12 months are especially featured. The information given will assist in determining sizes, power and speed ranges, and the services for which particular models are intended. In view of the almost endless variety of Diesel engines this guidance will be appreciated.

Fuels for Internal-Combustion Engines—by Gustav Egloff, W. H. Hubner and P. M. van Arsdell; reprinted from CHEMICAL REVIEWS vol. 22, No. 1 (1938).

The output of literature on hydrocarbon fuels from the research division of the Universal Oil Products Co. is vast and apparently as inexhaustible as it is valuable. Here is a monograph of 106 pages that surveys what is recorded about motor fuel from crude oil, motor fuels from natural gas, motor fuel from coal, motor fuel from oil shale, motor fuel from plants and wood, not to mention innumerable by-products in the form of chemicals—alcohols, ethers, ketones, etc. All these and the various methods of obtaining them—by cracking, thermal polymerization, catalytic polymerization, hydrogenation, etc.—are recorded and registered so that any one interested may track down necessary information. It is a vast subject and Dr. Egloff and his associates have rendered a very useful service in this and other treatises that systematize our knowledge of oil, its uses and possibilities.

The Cracking Art in 1937, by Gustav Egloff, Martha M. Doty and Jane F. Jordon, published by UNIVERSAL OIL PRODUCTS CO., Chicago, Paper cover, 397 pages.

This volume contains an analysis of the literature of the cracking art from January 1st to December 31st, 1937. That there has been a vast activity among research workers, investigators, engineers, chemists and inventors in this field is attested by the fact that 595 literature citations are necessary to cover developments of this single year, besides 251 pages devoted to an analysis of more than 700 patents issued in various countries. Certainly the art of cracking has and is still being most intensively studied.

The literature section is excellently arranged according to topics, which include the world status of cracking: pyrolytic, catalytic, electrical, and cracking with oxidation. Commercial developments in cracking: liquid-vapor phase, and selective cracking, vapor phase cracking and gasification. Cracking plant equipment. High Octane fuel from hydrocarbon gas including research in polymerization and alkylation, with commercial developments. By-products of cracking; and treating cracked products. The entries in the patent section are also classified so as to be easily consulted. There is an author index.

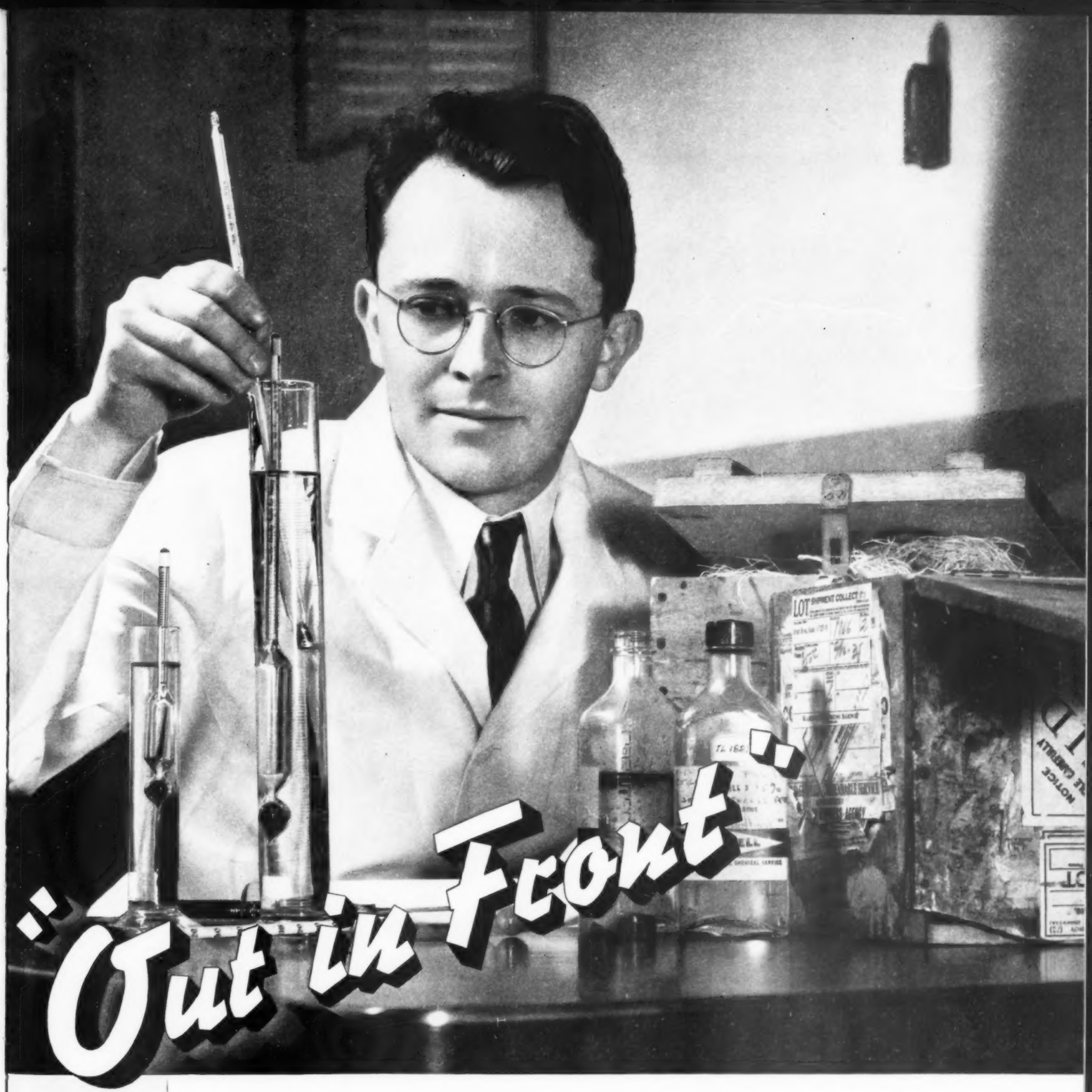
Petroleum Development and Technology 1938. Transactions of the American Institute of Mining and Metallurgical Engineers, vol. 127: Published by the A.I.M.M.E., New York; 744 pages, illustrated; $5.00.

This volume is the thirteenth of the Petroleum Developments and Technology series of the Petroleum Division of the A.I.M.M.E. It contains the papers presented at the Los Angeles and Oklahoma meetings in 1937 and the New York meeting (February) in 1938.

There are six chapters: Production Engineering; Review of Notable California Fields; Engineering Research; Petroleum Economics; Production, (a) domestic and (b) foreign. The sixth chapter is a review of refinery engineering by Walter Miller.

The chapter on production occupies half the book. It summarizes the year's activities of every field in the United States and sketches oil activities in every important foreign oil producing region. A voluminous index is provided.

Most of the papers printed in this book have been reviewed in the columns of WORLD PETROLEUM ABSTRACTS. They are all noteworthy contributions to petroleum literature. Any oil man's library will be graced and enriched by a collection of this annual series.



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Official Figures for Soviet Oil Operation

1938	Production bbl.	Daily Average bbl.	Run to Stills bbl.	Drilling feet
January	17,647,000	569,258	15,882,000	520,000
February	13,591,000	485,393	13,122,000	320,000
March	15,984,000	515,613	14,842,000	340,000
April	17,850,000	595,000	15,850,000	400,000
May	17,580,000	567,097	15,600,000	420,000
June	18,540,000	618,000	15,900,000	550,000
July	18,200,000	587,097	16,800,000	500,000
August	18,000,000	580,645	16,800,000	510,000
Total 8 Mos. 1938	137,392,000	565,340	125,596,000	3,660,000
Total 8 Mos. 1937	134,070,660	551,731	124,759,390	4,154,660
Total 1937	202,856,661	555,772	187,121,389	6,244,660
Total 1936	199,634,921	545,450	180,582,274	6,958,916
Quota 1938	244,215,000*	666,066	215,055,000	not available
Quota 1937	234,450,000	642,329	208,285,000	9,240,000
Quota 1936	222,345,000	607,000	192,250,000	7,100,000

*Crude oil and gas

Soviet Crude Production and Refinery Output in Relation to Exports and Domestic Consumption

Year	Crude Production (Metric tons)	Gasoline Output (Metric tons)	Export of All Products (Metric tons)	Gasoline Exports (Metric tons)	Domestic Gasoline Consumption (Metric tons)	Imports of Gasoline Natural Gasoline
1924	6,441,000	325,000	712,000	275,000	45,000	.....
1925	7,483,000	400,000	1,372,000	306,000	65,000	.....
1926	8,821,000	600,000	1,473,000	499,000	84,000	.....
1927	10,957,000	750,000	2,086,000	650,000	89,000	.....
1928	12,316,000	950,000	2,787,000	722,000	190,000	.....
1929	14,477,000	1,300,000	3,625,000	980,000	225,000	.....
1930	18,622,000	1,967,000	4,750,000	1,340,000	305,000	.....
1931	22,357,000	2,221,000	5,212,000	1,660,000	625,000	.....
1932	21,389,300	2,780,000	6,106,000	2,018,000	895,000	.....
1933	21,330,100	2,650,000	4,890,000	1,296,000	1,165,000	.....
1934	24,092,700	2,815,000	4,310,000	1,119,000	1,700,000	.....
1935	25,241,000	3,200,000	3,353,000	658,000	2,300,000	.....
1936	27,384,900	4,000,000	2,660,000	419,000	3,400,000	64,280
1937	31,500,000	5,000,000	1,930,000	350,000	4,500,000	181,675
1938	.....	.....	.....	.....	.....	152,062*

* Plus 819,474 tons of gasoline.

INTEREST has been aroused in Russian oil circles by the recent flight from Moscow to the Soviet Far East, for progress in aviation together with problems of national defence have again brought up the question of supplying high octane gasoline. Efficient high compression engines require fuel grades of 95-100 octane; modern motors for automobiles demand an octane rating of 70 while tractors in order to operate properly should have a 52 octane fuel against the 40 octane rating of the Soviet gasoline.

Physical refining is unable to provide a gasoline from Soviet crude which comes anywhere near the desired standards, and cracking was the first step taken to raise the anti-knock value. The Third Piatiletka will concern itself chiefly with introduction of chemical processes and petroleum gases are to overcome the disparity between the supply and demand of high octane gasoline.

Polymerization plants are being erected and the Soviet research institutions have accumulated considerable data on the improvement of the characteristics of motor fuel—knowing that iso-octane alone cannot solve the problem.

Even granting that the Soviet technologists are capable of designing refineries capable of turning out high-quality fuels, that the plants can be produced and the engineers are capable of operating them efficiently this does not necessarily mean that the desired product will be obtained, for sometimes such a plant is built but never used.

To cite examples—the Soviet cracking installation designed by Shukhov and Kapelushnikov, erected in 1934 at a cost of about Rbl. 1,500,000 and which by its reforming process offered aviation gasoline of high octane, was razed in 1936 while the second Soviet cracking installation, a process evolved by Prof. Dubrovaya, also erected in 1934, has been idle ever since its completion.

The Dubrovaya installation combines two processes which are said to be an innovation in the technique of petroleum refining. These are: vapor phase acidulation cracking and zinc-chlorine treating in the vapor phase. During 1937 this installation was put on stream for testing purposes and yielded gasoline of 81 octane rating and high stability, exceeding the quality of any other grade of Soviet gasoline. Besides gasoline of 81 octane, which could probably be raised by adjustments to the processing equipment, the unit yielded ligroin of 75 octane rating. An interesting feature of the process is that it is claimed that the system operates entirely without formation of coke —enabling the continuity of the processing cycle to be appreciably extended.

Dubrovaya's plant was tested over long periods and has thus yielded data sufficient for the design of a large industrial plant.

While the Soviet procrastinates over bringing its refining facilities in line with the country's domestic requirements, the disparity between production and consumption of gasoline is increasing. From 1930 to 1937 the gasoline consumption of the Soviet Union grew from about 300,000 tons to 4,500,000 tons, or almost 1,500 percent, while production rose to less than 5,000,000 tons from about 2,000,000 tons, or only 250 percent. Attempts at economy and rationing of consumption have done little to overcome this uneven increase; more effective have been the decreased exports which diminished from over 2,000,000 tons in 1932 to about 350,000 tons in 1937.

There has been a decrease in production of light crude grades since the Grozni fields began to decline and other factors contributing to the difficulties are: the slow rate of refinery construction, accelerated wear of existing plants (due for the most part to the Stakhanov system, which results in overtaxing the operating capacities), and the frequently faulty design and construction. Large quantities of the volatiles are lost from the crude by evaporation during transportation and storage.

Although plans to mitigate these evils were laid during the Second Piatiletka, no material results were obtained. Other measures considered to bring gasoline consumption more in relation to the supply available was a change in motive units of cars and tractors in the form of higher compression ratios and Dieselization. On the basis of 1937 figures, each percent of gasoline economy is equivalent to the output of an average cracking plant.

The rate of gasoline consumption per motor car in the U.S.S.R. is four or five times the amount used per unit in the United States (91.4 bbl. compared with 15.8, per annum). Corresponding figures for other countries are: France, 11.4; Germany, 18.0; England, 20.1; Italy, 10.6; Poland, 23.0; and Japan, 47.0. With so few cars in use and such a large gasoline consumption it is evident that in the Soviet

Adjusting Guide Head. The patented Guide Head of the Guiberson Spider guides the tubing to the exact center of the spider's bore, insuring accurate seating of slips.

Removing Elevator. Tubing is safe in this spider's grip. Men, left to right, are: T. W. Wade, John Spence, Jack Sims, Clyde Smith, (Toolpusher), and E. I. Caruthers.

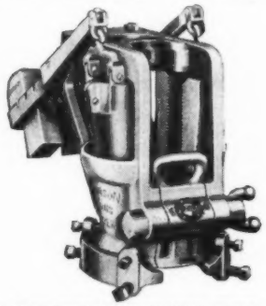
"THAT GUIDE HEAD IS A WONDERFUL IMPROVEMENT," SAYS CLYDE SMITH

Clyde Smith, fourth from left, second picture, in the employ of a major oil company at Edmond, Oklahoma, tells us that the patented "Guide Head" on the Guiberson Tubing Spider is a wonderful improvement in spider design. This exclusive patented device is so adjusted that it holds the tubing in exact center of the spider's bore, at all times, whether running or pulling—causing the spider slips to seat instantly and accurately around the tubing without handling or forcing by the men. The men's hands need not be placed near the slips.

"We don't drop tubing with this spider," Smith added, "and it's the only spider we ever used that won't slip in paraffin."

This new-day spider offers other outstanding and exclusive advantages, which render it as nearly automatic as a spider can be. The lever seats or retracts the slips at one motion of the hand or foot of the operator. It can be used with or without the adjustable weight. A safety latch holds the lever in raised position and the slips in bowl, preventing slips from being thrown from the bowl should the tubing rebound. Large opening through spider body passes tubing catcher, packer, or other tools. It is quickly installed or removed by simply removing bolt and gate.

These features make this spider speedier and easier to operate than any former design. The lever eliminates back fatigue because operator can stand erect, lowering or raising slips with his foot. Maximum safety is assured, because operator stands back from elevator and pipe.



GUIBERSON "HEAVY TYPE" TUBING SPIDER

It is made of steel throughout, in two sizes. The Heavy Type supports any size or weight of tubing at any depth; the Medium Type supports 5,000 feet of 3" upset tubing or its equivalent. Slips are made for 2", 2½", 3", and 4" tubing in the Heavy Type, and for 2", 2½" and 3" tubing in the Medium Type. Adapters supplied to fit any size and make of head. See it at your supply store. The Guiberson Corporation, Box 1106, Dallas, Texas.

Making Up. No back-up wrench is being used, as spider's grip is plenty powerful.

Running In. Slips are retracted by the lever. Men stand back at safe distance.

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Union motor vehicles are made to bear heavier utilization. The reasons that Russia's consumption per unit is so high are: (1) overloading and longer daily use; (2) inferior roads; (3) poorly-built motors in bad condition—compression ratio of four, while it is six in the United States; (4) octane rating averages 40 compared with 75-80; (5) evaporation; and (6) waste of fuel by drivers.

4.2 compression and require some 20 percent more fuel than the vehicle with a compression of 6. Soviet domestic machine shops may overcome the difficulty of increasing the compression, and other mechanical features (although it would require thorough re-designing) but it is questionable whether the octane rating of the gasoline produced would permit this increased compression.

While efficiency of the motor increases with the compression, at the same time compression increases require higher octane ratings. Thus a compression of 4.0 gives an engine a theoretical efficiency of 42.6, a compression of 5.0 gives theoretical efficiency of 47.5, compression of 6.0 gives efficiency of 51.2, and a compression of 7.0 means theoretical efficiency of 54. However, compression of 5.0 to 5.4 requires an octane rating of 65, 5.5 to 6.0 requires 75 octane and 6.1 to 6.5 requires 87 octane.

Soviet automobiles:	Compression
Light cars GAS A	4.1-4.2
Trucks 10-12 T. GAS AA	4.1-4.2
Trucks 3 T. SIS	4.6-4.8
Trucks 5 Y.S.	4.6-4.8
Tractors	Below 4
American automobiles (6-8 cylinder):	
60-80 h.p.	5.45-5.65
90 h.p.	6.33-6.70

In the United States the average compression rose from 4.35 in 1924 to 5.98 in 1935 while many European cars have even higher compression. Soviet motors average

SOVIET PIPELINES

FOR MANY YEARS crude oil from the Baku fields was carried to the refineries of Blacktown in barrels supported on two-wheel carts, called *arbars* over a dirt road and the track between the fields and refineries was covered by a long string of these carts all day long.

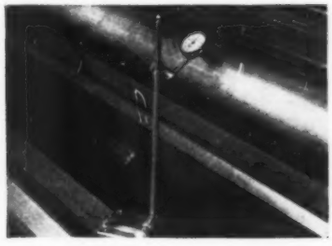
The Nobel brothers laid the first pipeline in Russia between Balakhani and Blacktown at a cost of about $50,000. At first the Tartars engaged in carting the oil gave violent opposition to this project and it was necessary to keep guards at frequent intervals along the line to prevent sabotage. While the other producers were at first sceptical of this scheme of pipeline transportation and declined to join Nobels, the success of the undertaking soon resulted in others following suit. Within a few years all the crude was transported to Baku in this manner. Several years after nationalization of the oilfields, the Soviet government un-

STARTING LIFE for A LINER'S "OVERCOAT," the PUMP JACKET

THERE IS NO ECONOMICAL SUBSTITUTE FOR QUALITY

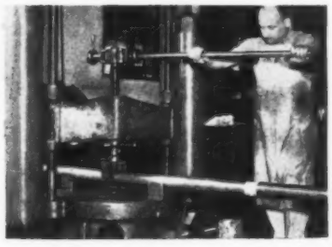
To the average user of deep well plunger pumps the jacket is merely a piece of tubing that holds a series of liners. To Axelson, however, pump jackets are important—so important that they are constructed of cold rolled material—requiring twenty-four manufacturing and inspection operations between the raw stock and finished jackets. ¶ After every manufacturing operation on any Axelson product a check is made by the machine operator to verify accuracy. These inspections are then further checked by regular shop inspectors. ¶ This care and attention to every detail of pump fabrication is one of the reasons why Axelson pumps have a world-wide reputation for long life and economical production.

1. Special cold rolled steel tubing of various sizes for Axelson jackets is stored in the tubing warehouse.

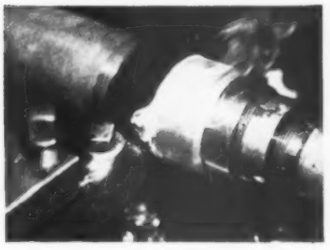


3. Axelson jacket material must meet definite specifications for straightness. This is checked with dial indicators.

2. All tubing is rolled to definite specifications and is carefully inspected immediately upon arrival.



4. Where misalignment is disclosed the tubing is straightened to conform to exact tolerances allowed.



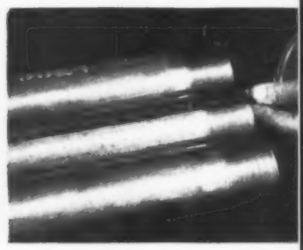
6. After chamfering the jacket ends, they are lathe turned to the proper size preparatory to threading.

7. Axelson chasers chase the thread on both ends of jacket. Threads are gaged before removing from machine.

8. As an added precaution, threads are again checked by an inspector after the lathe operator's check.

9. Next, a plug gage is passed through the entire length of each jacket, checking roundness and size of bore.

5. After straightness has been verified, jacket material is placed in Axelson lathes where ends are chamfered.



10. Inspectors verify that every Axelson jacket has been previously cut and finished to correct lengths and tolerances.

11. After all manufacturing and inspection operations, each jacket is painted and stenciled with its part number.

12. After painting and stenciling threaded ends of each jacket are coated with a special rust-preventive solution.

13. Finished jackets are carefully stored in Axelson stock rooms, for shipment or to be made up as complete pumps.

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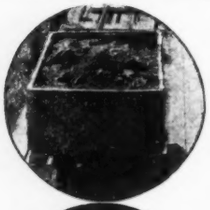

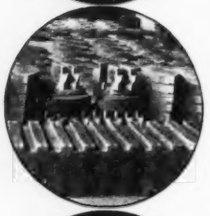

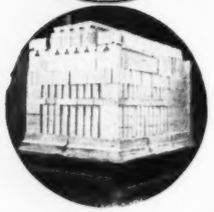

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dertook a reconstruction of these lines—after tearing up all lines duplicating each other they had retained a total length of about 330 mi. connecting the Baku refineries and fields.

idle, but became the main conveyance of shipments of Baku crude which were made to keep Grozni refineries on stream. It has now been decided to duplicate the line from Makhatchkala to Grozni.

Existing Soviet Pipelines

Terminals	Product	Length (mi.)	Diam. (in.)	Capacity (tons p.a.)	Substations (no.)	Built (yr.)
Baku—Batum	crude	498	8	1,000,000	16	1896-1900
Baku—Batum	crude	492	10	1,700,000	13	1928-1930
Guryev—Orsk	crude	440	12	1,500,000	11	1932-1933
Grozni—Maikop—Tuapse	crude	372	10	1,700,000	10	1927-1928
Grozni—Armavir—Ukraine	ref. oil	294	12	1,650,000	2	1931-1932
Grozni—Makhatchkala	crude	96	8	800,000	4	1913-1914
Ufa—Ishimbayevo	crude	88	10	1,000,000	2	1935-1936
Moigebek—Grozni	crude	72	10	500,000	..	1938
Maikop—Krasnodar	crude	66	8	900,000	1	1910
Guryev—Koschagil	crude	48	8	250,000	1	1935
Izberbash—Makhatchkala	crude	39	8	.....	..	1938
Grozni—Gorski Mountains	crude	34	..	1,800,000	..	1938
Makat—Dossor	crude	19	4	100,000	..	1927
Dossor—Rakusha	crude	4	6	200,000	..	1915
Baku gathering lines	crude	330	6-8	.....	..	1885-1937
Under Construction						
Trudovaya—Voronesh	.....	240	..	.....	..	1938-?
Trudovaya—Dnepropetrovsk	.....	120	..	.....	..	1938-?
Grozni—Makhatchkala	crude	90	12	1,500,000	4	1937-1938
Prevoloki—Volga shore	crude	21	..	.....	..	1938-?
Tuimazi—Ufa	crude	...	..	.....	..	Projected

For a number of years the Baku oil industry was cut off from all markets by lack of transportation facilities, other than by waterway over the Caspian Sea to the mouth of the Volga at Astrakhan. In the late 80's the Russian government had built a railroad between Baku and Batum, thus giving the oil industry an outlet to tidewater on the Black Sea. At first this could easily deal with the oil to be transported, but with the opening of exports the overseas market for Baku oil increased and the single-line railroad became congested with the heavy traffic.

Russian and British financial circles were ready to build a kerosene pipeline between the two points. The railroad, which was built at a cost of about $58,000,000, was operating at a loss of about $1,500,000 per annum and as the government did not wish to diminish the revenue of the railroad it refused permission. After a serious accident in 1896, delaying traffic for two months, the government decided to build a pipeline. The gradient of the railway from Baku to Mikhailovo was a steady one, while from the latter town to the summit of the mountain range was of a steep ascent necessitating a division of the trains into sections and use of additional locomotives—hence the first portion of the line was constructed along the 140 mi. from Mikhailovo to Batum. In 1900 the line was extended to Ag-Taglia, and then to Baku.

Grozni fields had experienced still greater transportation difficulties due to the fact that these fields had no outlet to any port. Shipment of Grozni oil to any point had to be made by railroad. In 1914 a pipeline was built from the fields to Petrovsk (Makhatchkala) and in 1927, after nationalization of the industry by the Soviets, the segment to Tuapse on the Black Sea was added. When in 1932 Grozni output fell from about 9,000,000 tons to about 3,500,000 tons this line to the Caspian at first became almost

In order to lower the maintenance costs, the line from Grozni to Armavir and the Ukraine, built in 1932, follows the Grozni-Maikop-Tuapse pipeline as far as the Vodorazdel depot, and from this point turns north and goes cross-country to Rostov, of the Don River. From the latter point the main line proceeds to Mikitovka and a spur runs along the railroad to Millerovo. From Mikitovka the line follows the left bank of the Don, feeding both the right and left sides of the river, the western district of the Ukraine and the entire district of White Russia and gets its distribution from Lozovaya. The pump station at Rostov has also a large tank farm at Nakhitchevan, on the Don. Originally it was planned to continue this line up to Moscow, but the project was shelved while in course of construction.This line is to be extended from its terminal at Trudovaya to Dnepropetrovsk, an important metallurgical center, and a second line from Trudovaya will extend to Voronesh, an agricultural center in the black soil district of Russia.

The Guryev-Orsk pipeline (440 mi. trunk line and 96 mi. gathering lines) was designed to carry Emba crude to Orsk, which is an industrial center in the east of the country. The line follows the steppes, which have practically no vegetation or water and population is scarce. The line has eleven pumping stations all equipped with Diesels.

The Astrakhan line runs for the most part on the bottom of the Volga river and connects the river terminal with the railroad to facilitate shipping. Caspian Sea tankers unload at this point and the oil is reloaded into barges or rail tank cars.

The recently-opened Daghestan oilfields are connected with the Caspian by the Izberbash-Makhatchkala pipeline. Izberbash and the adjacent properties of Achisu, Kayakent, etc., were discovered and put into operation during 1936, and with further producers are expected to add about

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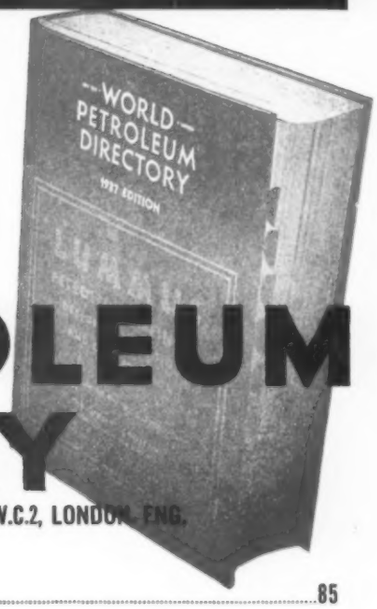

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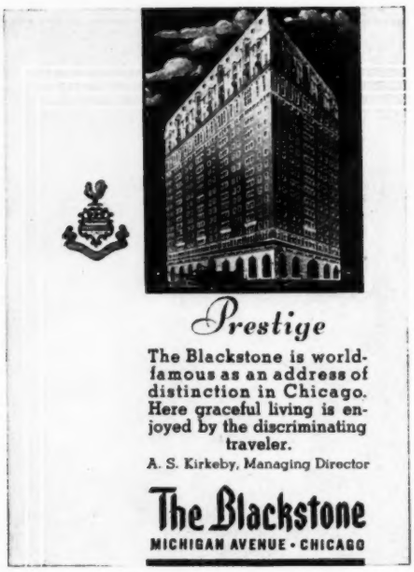
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1,000,000 tons to the total annual Soviet output.

Enormous crude production potentialities are reported in the Molgabek oilfield of the Grozni group, and a pipeline has been run to the refining center. This field in the Terski Hills was discovered in 1936.

The Ufa-Ishimbayevo line was completed at the end of 1936 to form an outlet for the Bashkiria oilfields. As well as the pipeline, a railroad was constructed from the field to Ufa. Another addition to the Bashkiria fields is Tuimazi, and a survey is being made for the construction of a pipeline from Tuimazi to Ufa.

All pipeline terminals and pump stations built after 1930 were provided with fairly modern equipment and were Diesel-powered, against the previous practice of using steam outfits or gas generators.

J. WEGRIN

GULF EXPORT PRICES FOR MAJOR OIL PRODUCTS

Products		Sept. 7	Sept. 14	Sept. 21	Sept. 28
		Cents Per Gallon			
GASOLINE:	U.S. Motor	4⅝	4⅝	4⅝	4⅝
	64/66-375 E.P.	4⅝	4⅝	4⅝	4⅝
	59 Octane and below	4⅝	4⅝	4⅝	4⅝
	65 Octane and above	5	4⅞	4⅞	4⅞
AVIATION GASOLINE:	Gulf Export in cargo lots	8¼	8¼	8¼	8¼
KEROSENE:	44 w.w.	4¼	4¼	4¼	4¼
	41/43 w.w.	4	4	4	4
	41/43 p.w.	4	4	4	4
GAS OIL:	43 Diesel Index and below	3½	3½	3½	3½
	43/47 Diesel Index	3½	3½	3½	3½
	48/52 Diesel Index	3½	3½	3½	3½
	53/57 Diesel Index	3⅝	3⅝	3⅝	3⅝
		Dollars Per Barrel			
FUEL OIL:	Bunker C	75	75	75	75
	Cargo lots	60	60	60	60
	Diesel oil	1.55	1.55	1.55	1.55
		Cents Per Gallon			
LUBRICATING OIL:	Bright Stock N . 8	21½	21½	21½	21½
	Bright Stock No. 6½	21½	21½	21½	21½
	600 Warren E.	20½	20½	20½	20½
	600 Unfiltered s.r.	15½	15½	15½	15½
(New York Export Market)	650 Unfiltered s.r.	17½	17½	17½	17½
	600 Flash s.r.	18	18	18	18
	630 Flash s.r.	20½	20½	20½	20½
	Neutral 200 No. 3	22½	22½	22½	22½
	Neutral 150 No. 3½	21½	21½	21½	21½
(South Texas Export Market)	Red oil 500 No. 5-6	7¾	7¾	7¾	7¾
	750	8¼	8¼	8¼	8¼
	1200	8¾	8¾	8¾	8¾
	Pale oil 500	7¾	7¾	7¾	7¾
	750	8¼	8¼	8¼	8¼
	1200	8¾	8¾	8¾	8¾
		Dollars Per Barrel			
CRUDE OIL:	East Texas delivered at Gulf for export	1.33	1.40	1.40	1.40

FREIGHT RATES

	Sept. 7		Sept. 14		Sept. 21		Sept. 28		Oct. 5	
	Dirty	Clean	Dirty	Clean	Dirty	Clean	Dirty	Clean	Dirty	Clean
Gulf-No. Atl.	17	16	17	16	17	16	17	16	18	16
Gulf-UK. Cont.	12/-	12/-	12/-	12/-	12/-	12/-	12/-	12/-	12/-	$1/-

HOLLAND'S PLACE IN OIL

UNTIL recently Holland has not been regarded as a refining center, although its West and East Indian colonies are of considerable importance in this respect in the international petroleum world. With the construction of a Shell refinery at Pernis, Rotterdam, the position of Holland has changed somewhat. During 1937 Holland produced the following.

Gasoline	1,366,777 bbl.
Gas Oil, Diesel Oil, distillate and fuel oil	468,266 bbl.
Lube Oil	not available
Coke	1,075,555 bbl.
Asphalt	702,399 bbl.
Various	296,726 bbl.
Loss	156,029 bbl.
	4,064,812 bbl.

It is estimated that with lubricating oil and kerosene the grand total amounted to at least 4,750,000 bbl.

WORLD PETROLEUM

NEW YORK AND LONDON

ANNUAL REFINERY ISSUE 1938

Courtesy A. O. Smith Corporation. Prepared by Henri, Hurst & McDonald, Inc.

OIL INDUSTRY PATENTS

COOPERATION IN RESEARCH

TREND IN REFINING

HOUDRY PROCESS

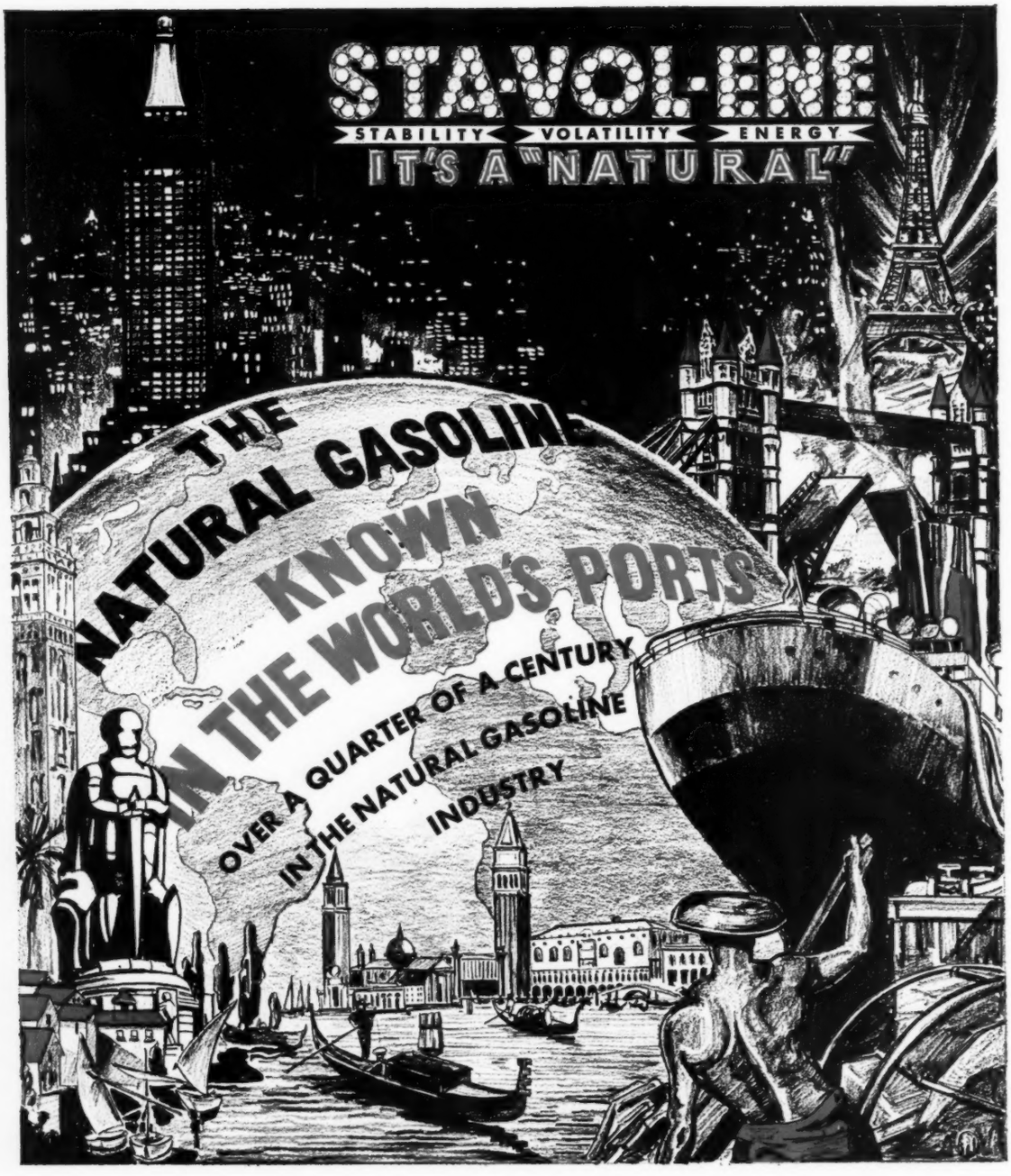
RESISTANCE TO CORROSION

SOLVENT REFINING COSTS

PIONEERING IN DESIGN

SLUDGE CONVERSION

MANCHESTER REFINERY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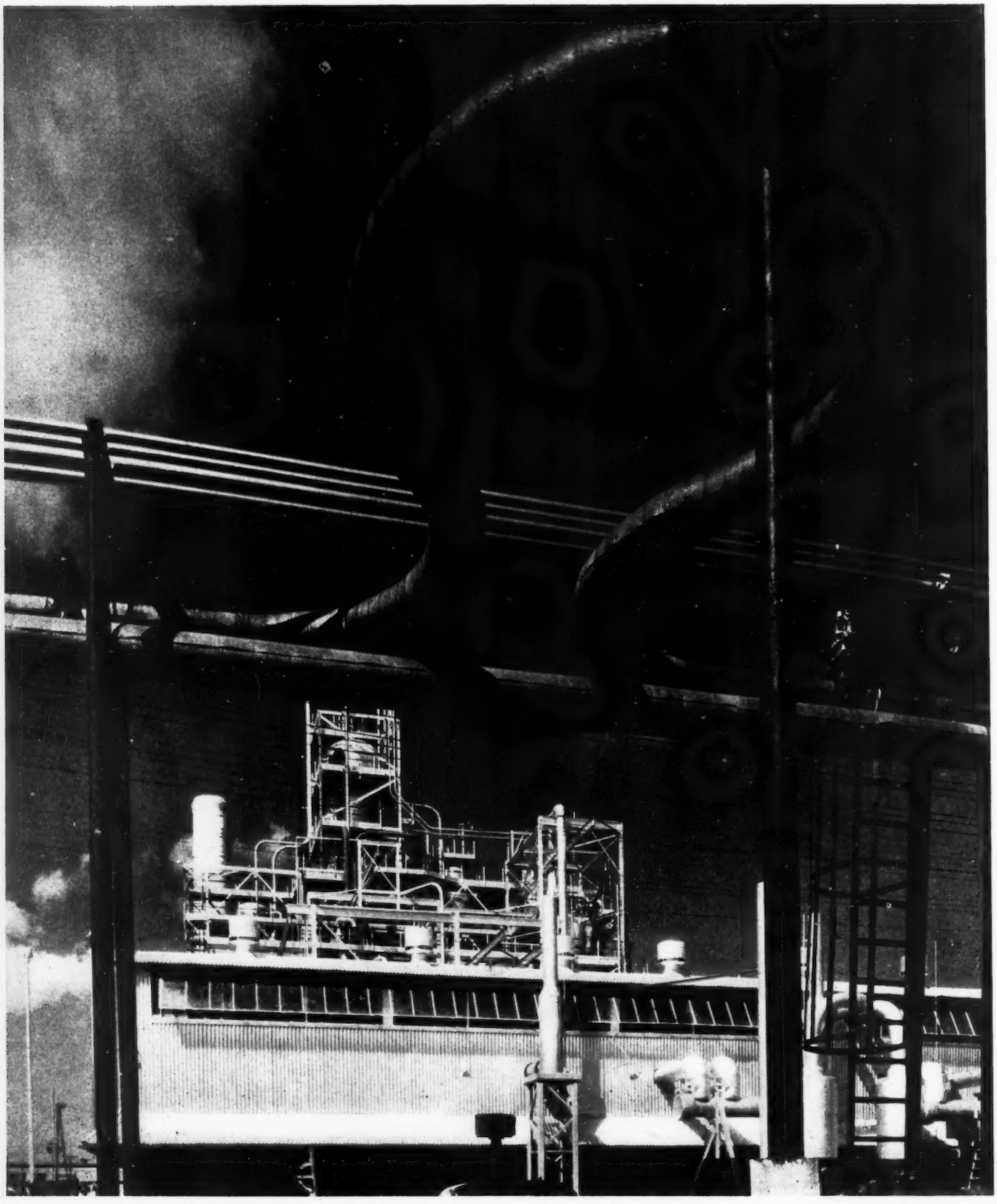

Courtesy the M. W. Kellogg Co.
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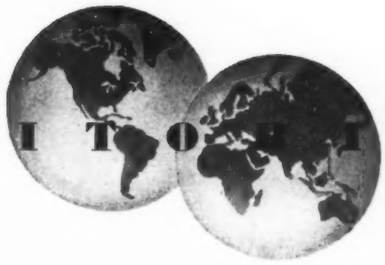
Part of the Baytown Refinery of the Humble Oil & Refining Company in Texas



REFINING—A PROGRESSIVE ART

REFINING is above all else a constantly progressing art. From the days when it was a matter of simple distillation it has advanced far, has become increasingly complex in many of its phases, but always it has been directed toward meeting changing demands and more exacting requirements imposed upon petroleum products by the developments of the machine age. Thus far, no task has been set before it by the demand for more efficient engine performance or by heavier pressures applied in the mechanical transmission of power that it has been unable to meet. The fact that these demands are continually assuming new forms and presenting new problems acts as a stimulant to those engaged in research and experimentation to press on to new achievements and to keep this record clear.

Writing a few years ago of the progress of petroleum a well-known commentator made the suggestion that the process side of the industry was the one that would show the greatest advancement in the future. That prediction is being verified at the present time. Catalysis and synthesis are the instruments with which investigators today are working to produce new combinations adapted to tasks more exacting than any that formerly were set before the industry. It is no accident that attention is being concentrated upon the more economical production of high-octane fuels, upon the mixing of hydrocarbons of varying characteristics to provide more durable and efficient lubricants, upon hydrogenation, polymerization, isomerization and other methods of synthesization for obtaining not only superior products for established uses but also important by-products in the chemical field. Along this road no limit to further progress is now in sight.

While petroleum plays a more important part than ever before in performing the work of the modern world the product in its natural state, with few exceptions, no longer is capable of accomplishing the tasks set for it by modern industry. It must undergo the transmutations which science and invention have made possible through ever more efficient refining processes in order to perform these tasks acceptably. Significant of progress in this direction is the fact that cracking, originally accepted as a means of utilizing inferior crudes, has progressed to the point where it produces more than half the total supply of motor fuel and where it promises ultimately to bring about the total disappearance of straight run gasoline, aside from a few exceptional crudes valuable for blending.

Investigation and experimentation dealing with the utilization of chemical processes have assumed particular importance, not only because of the promises which they hold out of broadening the range and improving the quality of products, but also because of the possibility of finding more economical methods than have been in use heretofore for obtaining certain products, such as high test aviation fuel for which demand is rapidly increasing. In this field also lie the most favorable expectations of giving greater flexibility to refining operations, an achievement that is desirable commercially as well as scientifically.

The immediate economic problem before the refining industry is to develop means by which the total supply of crude may be converted into products in such proportions as are dictated by market demand in order to avoid the accumulation of unwieldy surpluses in one branch or another of the industry. Judging by the success that has attended efforts to solve previous problems it is not too much to expect that further progress will result in putting an end to unbalanced production.

PATENTS—Their Contribution to Petroleum Progress

Policy of Making Patented Processes Available to Refineries on Reasonable Terms Has Enabled Industry to Keep Abreast of Growing Refinements and Has Cheapened Cost of Its Products.

TRITE perhaps but still true is the saying that necessity is the mother of invention and invention the mother of civilization. Progress in civilization from the beginning of human history has come from the creation of new wants and of the means to satisfy them. Man himself creates nothing but he discovers new ways of combining and applying existing elements and forces which enable him to add to his productive powers and to the satisfaction of his desires. These discoveries are the inventions that contribute in greater or lesser degree to the efficiency and comfort of life on the small fragment of the universe that we inhabit. Because this is so it has long been recognized that those who originated useful inventions were entitled to special honors and rewards.

The rapidity of material progress from the beginning of the industrial age has been due to the multiplicity of inventions within that period. The exceptional advance of America has been due in great part to the fact that her citizens have led the world in the number of their inventions and in the processes and products that have grown out of them.

Invention in one field of industry creates the necessity which becomes the mother of invention in another. The history of petroleum affords many examples of this truth. One is particularly conspicuous. As is well known the first broad commercial use of petroleum was as an improved illuminant. Kerosene was the one derivative in demand and all effort was concentrated on its production. The lighter fractions had to be eliminated as a measure of safety and were thrown away because no use had been found for them. During this period many improvements were made in the refining process and numerous inventions contributed to a higher quality and a greater recovery of kerosene. Later on gas and electricity to a certain extent displaced oil as an illuminant but the development of the internal combustion engine brought about a swiftly expanding demand for the very product that previously had been discarded as a useless and dangerous waste. From the turn of the century on the oil industry was forced to readjust its operations and to find more and more gasoline for use in the myriads of motor vehicles that grew in number until they practically monopolized the public highways.

In 1900 the number of motor vehicles in the United States was 8,000; at the beginning of 1938 the number was close to 30,000,000. More than 750,000 motor boats ply coastal and inland waterways. The airplane fleet consumes more than 2,500,000 bbl. of gasoline yearly. Total consumption of this form of motor fuel in 1937 was 519,000,000 bbl. By the beginning of the current year the world total of motor vehicle registrations was over 43,000,000 with fuel requirements of 760,000,000 bbl.

In 1900 the average barrel of crude oil containing 42 gal. yielded the percentages of products shown in the accompanying table.

Average Yield per Barrel (42 Gal.) Crude in 1900

PRODUCT	PERCENT	GALLONS
Gasoline	12.9	5.4
Kerosene	57.6	24.2
Lubricating Oils	7.6	3.2
Heavy Oils	14.0	5.9
Waste & Misc.	7.9	3.3

With the use of motor cars almost doubling from year to year in the following decade (Sixty times as many cars were in operation in 1910 as in 1900) it was impossible to meet the soaring demand for fuel on this basis of operation even though new oil fields were being discovered and crude production was increasing rapidly. By a simple process of distillation it was possible to increase to some extent the recovery of gasoline for which there was an almost insatiable demand. At the same time the quantity of heavy oils produced was automatically increased. Consumption of these gas and fuel oils likewise was increasing though with nothing like the rapidity of the expansion in the use of gasoline. The latter was the controlling factor and the effort of the refining industry was concentrated on obtaining more and more of the light fractions of the crude at the expense of the kerosene output. By 1914 the United States census showed a total of 176 refineries in the country. All of these operated on the same principle and were what is now known as skimming and topping plants.

Even before this time it had been known that the application of high temperatures to the heavier of the hydrocarbons that compose petroleum would produce a chemical change or separation. By this means certain fractions were converted into lighter and lower boiling hydrocarbons leaving the residue in the form of heavier hydrocarbons and gas. For several years technical men in different places were experimenting in the effort to place this operation, which came to be known as cracking because it involved the breaking down or separation of the hydrocarbons from their original forms, on a commercial basis.

In 1913 the first commercial installation was made. Its stock was gas oil and the heavier oils remained unavailable for the production of gasoline. A start had been made, however, and thereafter progress was rapid. Several cracking processes were developed embodying distinctive features and improvements over earlier methods. By 1920 a large number of units were in operation and it was practicable to crack heavy oil as well as crude stocks containing no natural gasoline. In this way the yield of gasoline from the crude was doubled and the quantity of gasoline producing oil available was multipled by four. Meanwhile the relative proportions of various products recovered from a barrel of crude had changed materially from what it had been twenty years before and averaged about as shown in the accompanying (1920) table.

Average Yield per Barrel (42 Gal.) Crude in 1920

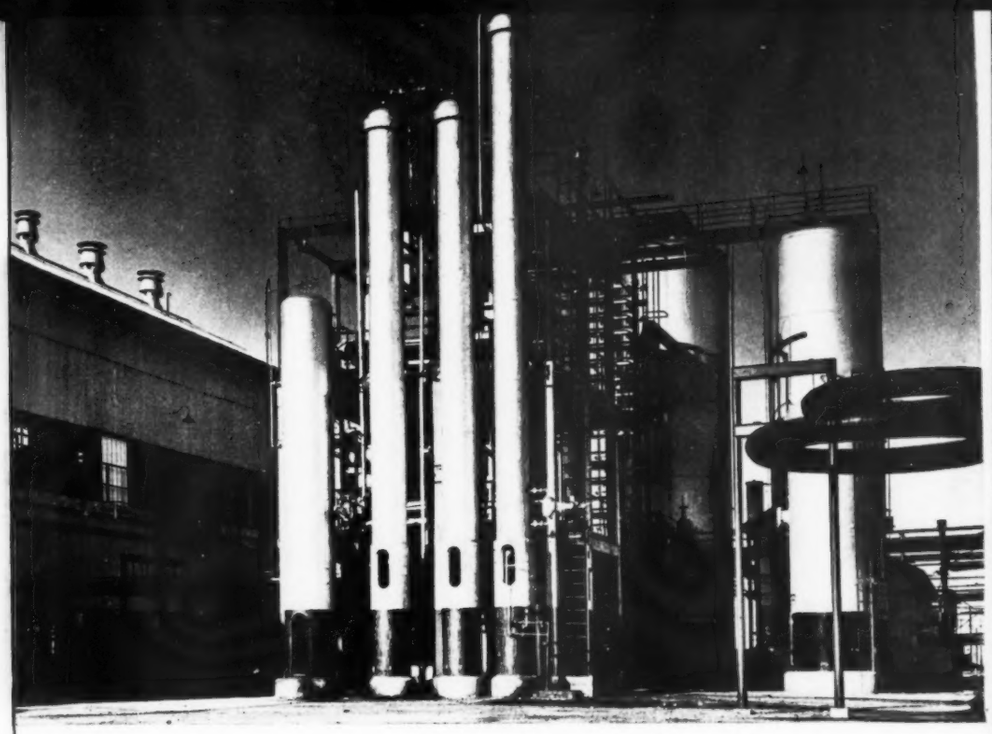
PRODUCT	PERCENT	GALLONS
Gasoline	25.7	10.8
Kerosene	10.0	4.2
Lubricating Oils	9.0	3.8
Heavy Oils	50.0	21
Waste & Misc.	5.3	2.2

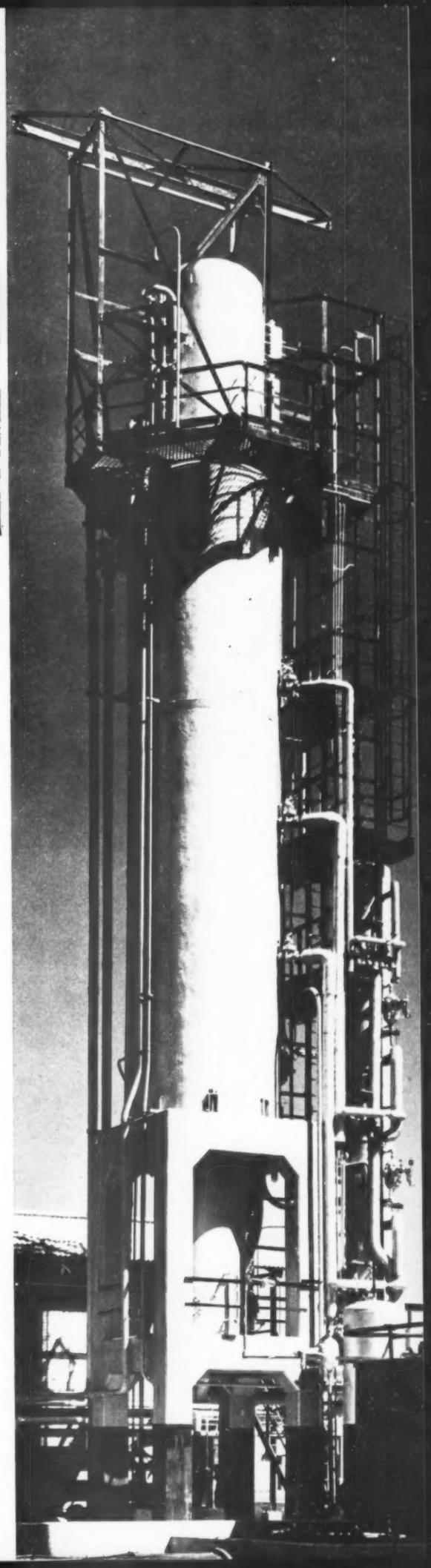
Since 1920 cracking has come into its own. It has spread around the world and a constantly increasing proportion of the total supply of motor fuel has been produced by cracking plants.

In 1936, for the first time the output of cracked gasoline exceeded that of straight run in the United States. Since then its growth has continued and for the first six months of 1938 production was divided as follows:

Straight run gasoline, 44.7 percent; Cracked gasoline, 48.6 percent; Natural gasoline, 6.7 percent.

Cracking is beyond doubt the most important development in the history of the petroleum industry to date. Laws and voluntary agreements for the conservation of petroleum resources have been adopted with more or less indifferent success but the greatest single agency for conservation has been the application of cracking.





Details of large modern refineries operating on patented processes. Courtesy, Gulf Oil Corp.; photos by Robert Yarnall Richie.

Through its use the quantity of motor fuel obtained from a barrel of crude has been more than doubled. One barrel of crude has been enabled to do the work of two or three so far as its most important product is concerned. Except for cracking over 4,000,000,000 bbl. of crude would have been required to supply the world demand for motor fuel in 1937 instead of the 2,023,000,000 bbl. actually used. Except for the invention of cracking processes it would be impossible for 43,000,000 motor cars to be in operation in the world today.

The reason for including this outline of the history of cracking in a discussion of the part played by patents in petroleum refining is that all cracking processes that have commercial value are patented processes. Without the possibility of financial reward from the control of patents it is unlikely that the men who originally discovered these processes would have carried on the long and discouraging course of study and experimentation necessary to make them workable or that other men would have continued the investigations that have since added to their efficiency and have made possible the progressive cheapening of their products.

There is a popular notion that inventions come as the result of a lucky guess or a sudden inspiration on the part of the inventor. It is true that patent office files are crowded with designs of contraptions that aspiring individuals have worked out on the spur of the moment for lightening one or another of the world's tasks. Very, very few of these have any practical value. Worthwhile inventions are evolved as the result of painstaking study and experiment, often extending over a long period of years and sometimes not completed within a span of a single lifetime. As industrial operations become more complex, and especially as improvements in methods become more and more a matter of applied physics and chemistry, invention tends to become a product of group effort worked out through carefully organized and long continued research. Such work requires resources and equipment that are seldom at the command of an individual. Progress in manufacturing methods and mechanical equipment tends accordingly to be centered in groups devoted wholly to research, whether these be independent organizations, institutes supported by trade organizations or special divisions of big corporations.

Here we encounter one of the arguments put forth by those who criticize the patent system. Because inventions nowadays are so expensive only large aggregations of capital can devote to them the time and research necessary or have the funds to acquire them from others by whom they may have been developed. Thus, it is claimed, important patents come into the control of corporations and so become an instrument of monopoly.

This argument would have more weight if inventions were held by large corporations for their exclusive use. In the oil industry at least the actual procedure is the exact opposite. When a new process or a new piece of equipment reaches the stage of practical working value it is made available to all those who wish to make use of it. It is offered of course at a price, but the price, as a matter of economic necessity, must be low enough so that the process or the machine will bring the buyer more

than it costs him. Otherwise he will not purchase it.

Take the matter of cracking as an example. Patents covering the various cracking methods and applications that grew out of these in many cases were taken in the name of inventors employed by oil companies or in others were purchased by such companies.

In point of fact only companies operating on a fairly large scale were in a position to utilize such processes in their earlier stages of development.

Incidentally these patents were the subject of extended and expensive litigation. The net result was to create a great deal of confusion so that a refiner who wished to install a particular process could never be sure that he was not buying a lawsuit at the same time. Without attempting to trace all the steps by which present results were arrived at it is sufficient for the purposes of this discussion to say that at present there are two large organizations whose sole commercial activity is the licensing of processes and the provision of the engineering services needed for their installation and operation. There also are numerous smaller organizations owning and licensing other special processes and equipment while a number of oil companies continue the direct handling and licensing of improvements that they have developed.

Of the two companies most prominent in the licensing of cracking processes one is the Universal Oil Products Company which owns and licenses the well-known Dubbs process with installations in all parts of the world. The other is the group of corporations affiliated with Gasoline Products Company which controls the Cross, de Florez, Tube and Tank and other processes. Besides these there are a number of other processes that remain the property of various oil companies or of individual owners. It is perfectly possible for any refiner, large or small, to obtain the use of any of these processes. Not only are the companies owning or controlling these processes willing to grant licenses to any operator without regard to his location or competitive activities but they promote the use of their processes by extensive advertising and other up-to-date methods of salesmanship. Incidentally, the terms on which the licenses are issued are uniform in the cases of all licensees, being based on actual throughput.

In the earlier stages of their operations the fee charged was fifteen cents for each barrel of oil charged to the cracking units. Subsequently it was reduced to ten cents and on October 1, 1938, it was lowered further to five cents. These successive reductions have been made possible by the increasing use of the various processes. In effect the system has worked as a cooperative enterprise, the benefits of increasing use being shared by all users although ownership remains in the hands of the licensing corporations. Even this does not satisfy some critics of the patent system. Ownership of patents by large companies, they contend, enables these companies to exact tribute from the smaller refiners which they can use in fighting the latter. The shallowness of this argument is so obvious that it hardly deserves an answer except for the fact that it has been advanced on more than one occasion. Aside from the fact that competition in the oil industry is not a matter of division between larger and smaller companies the receipt of revenue from participation in the ownership of a patent differs nowise from revenue derived from any other kind of property. Such ownership represents a large investment of capital. If the investment was soundly made it should bring a reasonable return. As well say that an oil company owning an office building, as some do, enjoys an advantage over a competitor who leases space in that same building. The owner pays no rent though all too often he pays out in taxes and upkeep more than he receives from all his rentals. But neither transaction has any relation to the sale of petroleum products on a competitor basis.

While the progressive development of cracking represents the most important forward step in the history of petroleum refining there are, of course, many patented processes which have no relation to cracking. Among them are the various systems of solvent extraction, making possible the production of lubricating oil from crudes formerly not suitable for this use. Methods of polymerization for the use of former waste gas in the production of high octane oil is another containing great possibilities for the future of the industry. In all of these

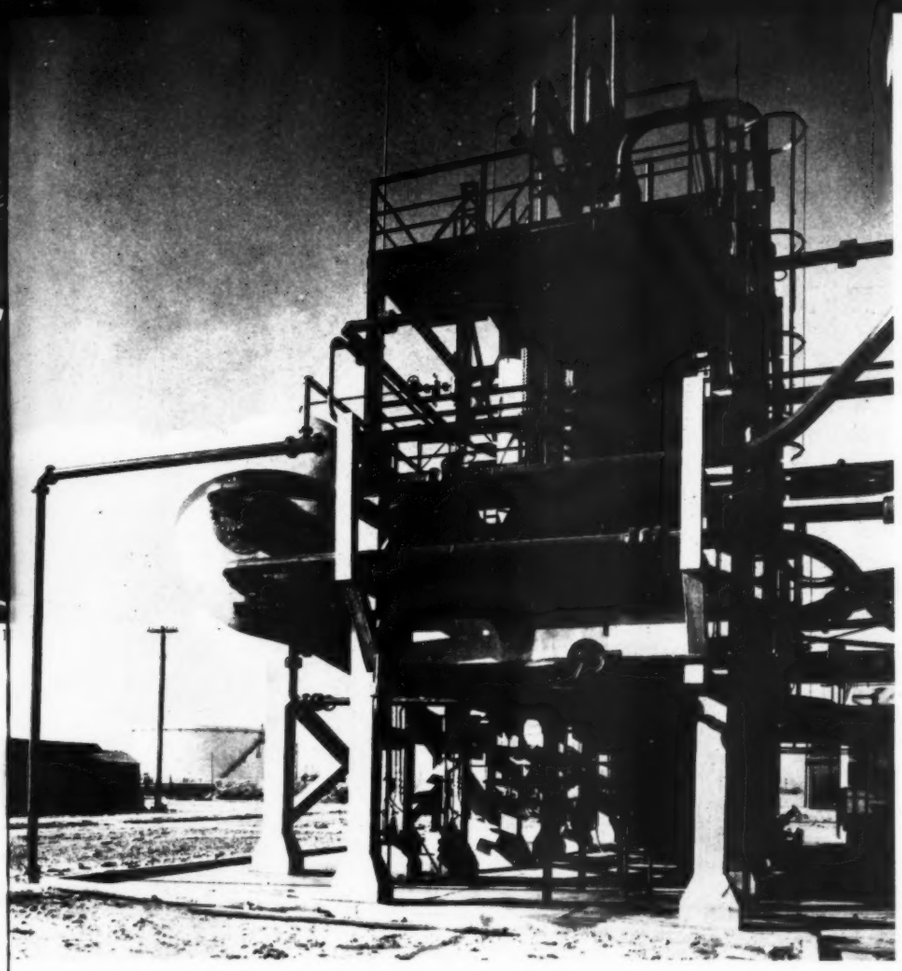
Photo by Robert Yarnall

In these tanks are stored temporarily high quality products now available to the public more cheaply than the inferior motor fuels of 10 years ago.

the same system that has been adopted in the case of cracking is being followed. The processes are made available to all who wish to use them on terms of exact equality.

Just recently one of the large licensing corporations installed in a small American refinery a polymerization unit treating 170,000 cu. ft. of gas daily. The plant cost about $10,000. A company with this small output in the ordinary course of events never would have been able to conduct the research necessary to the development of the polymerization process. On the other hand the controlling corporation never could have made such a small installation except for the experience and the profits derived from installing many much larger units. One of these larger units processes 27,000,000 cu. ft. of gas per day and costs about $1,400,000. Instead of handicapping the smaller operator the development and licensing of patented processes as operated in the oil industry has been the only means of enabling the small refiner to keep abreast of progress and to maintain a competitive position.

Instead of being an instrument of oppression the patent system as it is operated in the petroleum industry has been the salvation of the small refiners who wish to keep their plants on a basis of high operating efficiency. Had the oil companies that developed or acquired patentable improvements chosen to keep these for their own exclusive use, which of course was within their legal right, there would not exist today the situation in which the greater number of the refineries in the United States are in the hands of the smaller oil companies, nor would gasoline be selling at half the price charged for it no longer ago than 1920 despite the fact that demand



Modern plants have been made possible by research on the part of major units in the petroleum and engineering industries. Photos published through courtesy of the Gulf Oil Corporation, taken by Robert Yarnall Richie.

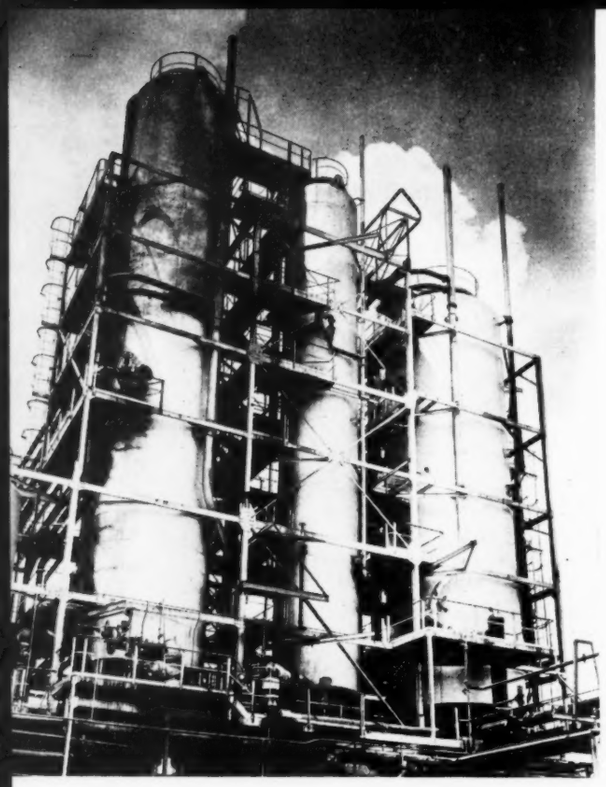
has multiplied nearly fivefold within that period. Not only the oil industry itself, including the smaller units, but the consumers of its products as well have benefited by the wide application of its most important technical advances. Moreover, clarification of the patent situation and the agreements among proprietary companies permitting the use of selective features of different patented processes have made possible the combination units so widely installed during the past five years which are recognized as embodying an important practical step toward higher operating efficiency. To the licensee an extremely valuable advantage of the present situation is that he can install up-to-date refining equipment with complete assurance that he will be protected against damage suits for infringement, the two large licensing corporations heretofore referred to assuming all such responsibility.

As has been mentioned previously most of the important improvements in the refining art are the result of research conducted on a broad scale. All the larger oil companies maintain research departments of greater or smaller dimensions. Exact figures of the amount expended in the field of investigation and experimentation are not obtainable but dependable estimates place the figure at $12,000,000 to $15,000,000 yearly. Likewise, the corporations that are engaged in the licensing of patented processes find a principal field of activity in carrying on research in laboratories of their own or in cooperation with oil companies and public institutions. One of the large process licensing corporations maintains a staff of between 600 and 700, the majority of whom are employed in research. The cost of this work is by far the largest item in its whole operating expense. Thus, money that is paid in royalties for the use of established processes to a very large extent goes to maintain the search for increasing recoveries, utilizing wastes and improving the quality of products. Much of this research, of course, never becomes embodied in practical application but out of it have come the newest and most promising attainments in adding to the efficiency and public service of the petroleum industry.

One of the charges made against the patent system is that it increases the cost to consumers of the patented article or the product of a patented process. In a book published only a few months ago the direct assertion was made that the existence of patents on the processing of petroleum increased the cost of petroleum and that "the consumer pays the price in the end." No facts were advanced in support of this allegation. In reality the facts overwhelmingly demonstrate an exactly opposite conclusion.

Without the invention of cracking methods it would be impossible for the oil industry to supply the quantity of gasoline now consumed each year. To hold demand within the limits of available supply prices would have had to rise far beyond the level of twenty years ago instead of decreasing steadily as they have done. In 1920, which may fairly be taken as the beginning of the cracking era in petroleum refining, the production of crude oil in the United States was 443,000,000 bbl. Consumption of motor fuel was 109,000,000 bbl. In 1937 the demand for gasoline had grown to 519,000,000 bbl. At the rate of recovery prevailing in 1920 the quantity of crude that would have had to be produced to satisfy this demand would have been over 2,000,000,000 bbl. Actual production was 1,100,000,000 bbl. in round figures. On the other side of the picture let us glance at the movement of prices. In 1920 the average cost of gasoline to the consumer as represented by service station prices less taxes was 29.7 cents for a gallon. In fourteen of the eighteen years since that time the price has registered successive declines and in 1937 the average service station price ex tax was 14.58 cents per gallon. Nobody can seriously contend that it would have been possible without the development of cracking to double the supply of motor fuel in eighteen years while halving its cost. Instead of the consumer being taxed to pay profits to the holders of petroleum patents the consumer has been the greatest gainer of all by the advances that have taken place in the industry and by the spread in the use of improved and patented processes.

One of the subjects scheduled for examination in the so-called monopoly investigation which is about to be conducted by the federal government in the United States is the relation of patents to monopoly. Among the specific subjects of inquiry which have been announced are the relation of patent ownership to competition, the suppression of developments from patents, patent pools and the possibility of making patents available to all who will pay royalties. If an investigation along these lines is extended to the oil industry and conducted impartially it will show that in this particular industry, whatever may be true of others, patents have not been suppressed, have not restricted competition, but have been made available to all potential users and have contributed greatly to the progress of this industry and to cheapening the cost of its products to consumers.



Above, tower structure of a modern combination cracking unit. Below, 19,000 bbl. of gasoline are produced per day from this combination cracking unit, with a charging capacity of 33,000 bbl. per day.

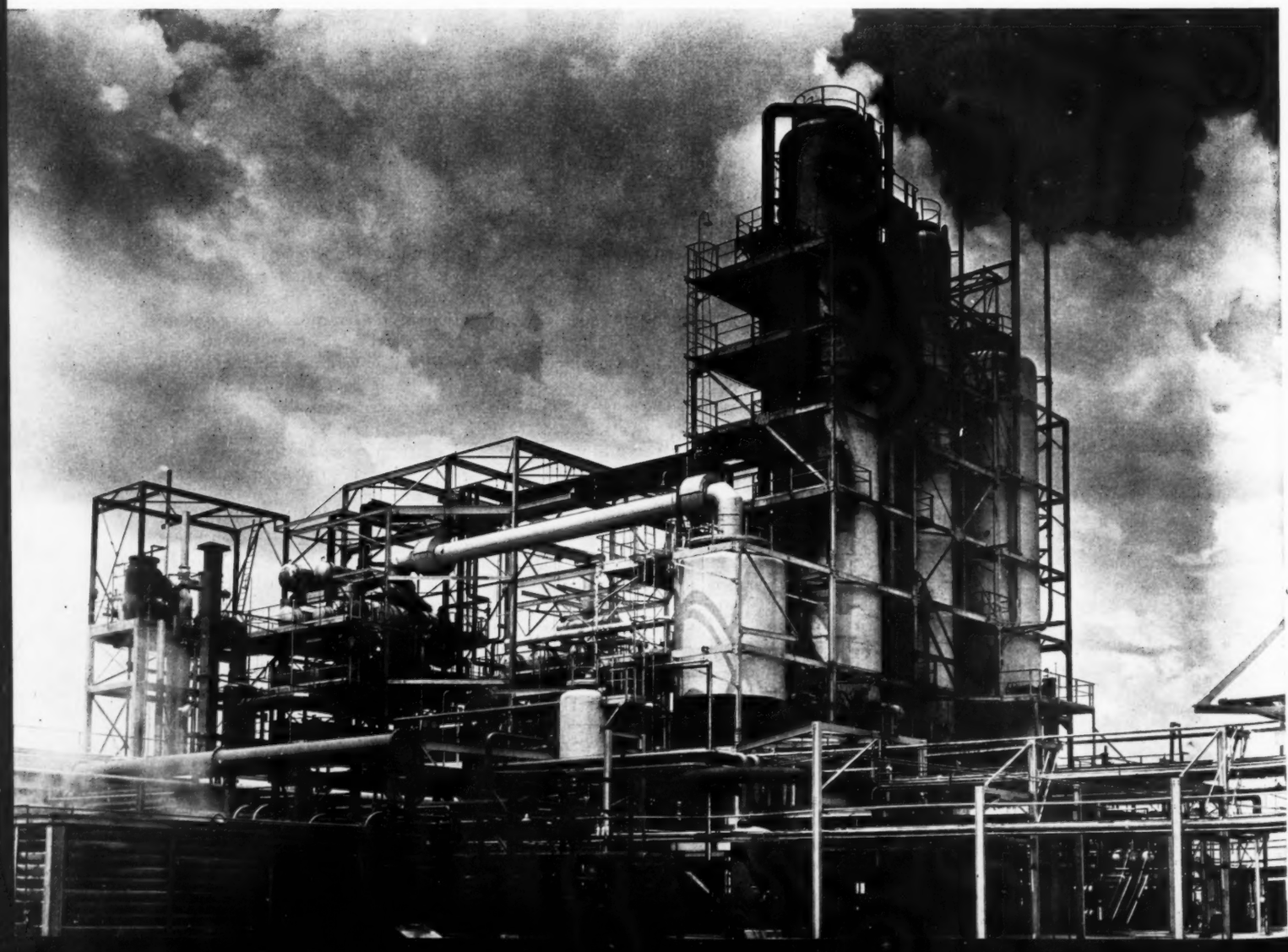
COOPERATION in Research Responsible for Increased Refining Efficiency

HUNDREDS of books have been written, and thousands of speeches have been delivered describing the benefits derived from many forms of cooperative endeavor. Cooperative wholesaling—cooperative retailing—cooperative buying—and many other methods of cooperation—have been publicized and practiced with varying degrees of support and success ever since the inception of the cooperative movement in Rochdale, England, almost 100 years ago.

Little, however, has been printed or spoken concerning the cooperative research and development work done in the pyrolytic cracking section of the oil industry during the last two decades—work which has resulted in the development of processes the use of which has benefited both the refiners using them and the users of gasoline. This is because they have made possible the more efficient production of better gasoline and at the same time reduced gasoline prices to the ultimate consumer. These processes have also played an important part in helping to conserve the world's oil resources—as will be shown later in this article—and this fact alone makes the story of how they were developed interesting and informative reading.

A brief history of the background from which cracking processes were evolved will be necessary to reach a clear understanding of the cracking art of today, its technical and patent aspects, and the enormously important part which cooperative research and development work have played in its growth.

Around 1910 experimental work was begun by W. M. Burton and R. E. Humphries at the Whiting, Indiana, plant of the Standard Oil Company (Indiana), to develop a process for the chemical decomposition, or cracking, of hydrocarbon oils for the making of gasoline. On July 3, 1912, the original patent application was filed and on January 7, 1913, the first of the Burton patents was



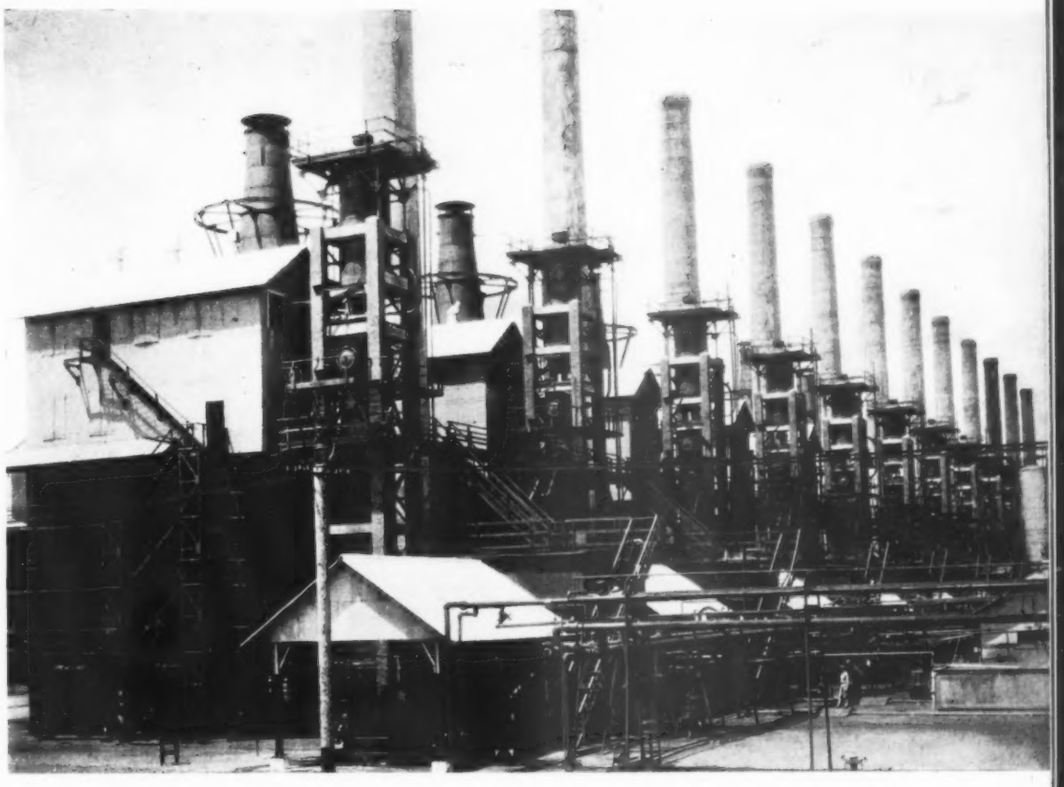
issued. During the year 40 Burton units were built at the Whiting plant and these—with the original experimental units—formed the first commercial cracking plant to be put in operation. The Burton method of cracking consisted in heating the oil in a still by external firing, to a temperature of about 750 deg. to 800 deg. F., and distilling off and condensing gasoline formed by decomposition while maintaining a pressure of 75 to 100 lbs. on the still and condenser. Basic patents covering this principle were issued and as fast as various improvements were developed by the research work which has never stopped other patents covering these improvements were secured.

So successful and profitable was the operation of the first Burton cracking units that the Standard Oil Company (Indiana) installed a large number of units and also licensed numerous other companies to use the process.

At first the Burton process was conducted on the batch principle, that is, the entire cracking operation was carried out on an original quantity of feed oil. Another characteristic of the process was that heat was applied to the oil in the vessel in which the cracking was taking place; consequently the condition of the oil under both heating and cracking was the same. Improvements in the Burton process were made later by Burton and Humphries and also by E. M. Clark, the most important of these being the adding of tubular heating surface in the fire box below the shell still. This modification greatly increased the output because of the greater heating surface and because the circulation of the oil through the tubes reduced the carbon deposits on the heating surfaces. Another most important improvement in connection with this process was the discovery of the hitherto unsuspected advantages of the bubble tower used as a part of the cracking unit under pressure.

The Dubbs cracking process—the first patent for which was issued on January 5, 1915—covered the distillation of oil under a self-generated pressure and resulted in some of the earliest patent litigation in the field, an infringement suit by the National Hydrocarbon Company—then owner of the Dubbs patent—against the use of the Burton units by the Standard Oil Company (Indiana).

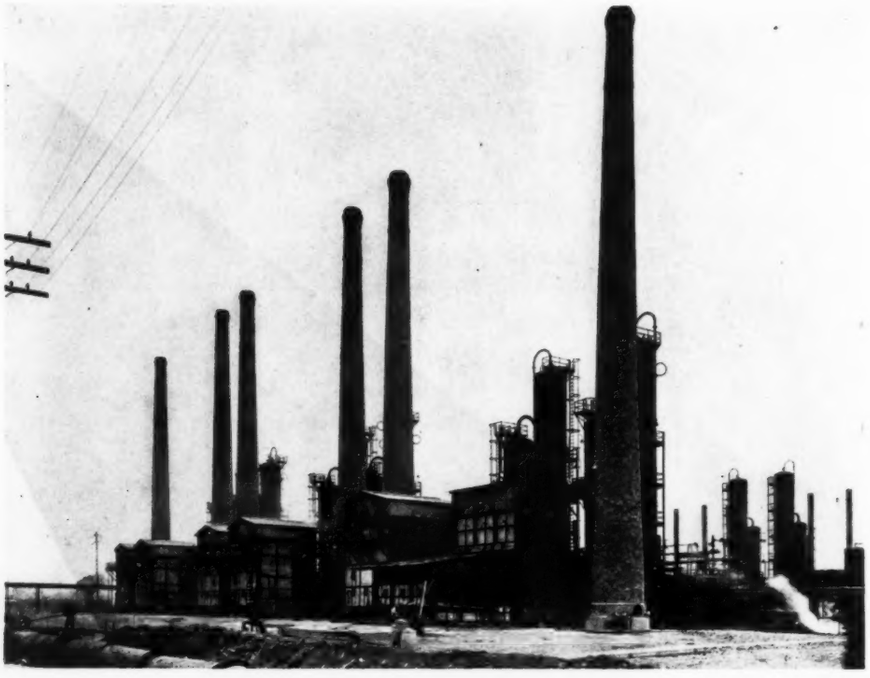
The Holmes-Manley process—which embodied in its design certain features of the Burton process and which was the first of the continuous processes to be commercially developed—was under development at about the same time as the Dubbs process which, in turn, exhibited several points of similarity to it. The Holmes-Manley process introduced the feature of clean circulation, using the hot oil pump for returning insufficiently cracked distillate fractions to the heater for retreatment. This important discovery was the invention of Otto Beheimer, who was a research worker in the Port Arthur refinery of The Texas Company. The development of the Holmes-Manley process resulted from lengthy experiments carried out over a period of years under the supervision of Ralph C. Holmes and Frederick T. Manley who were then in charge of the refining department of The Texas Company. It was one of the first continuous processes developed and soon became popular. The Texas Company built many units for its own use and also licensing several other refineries to use it, and by 1928 over 150 Holmes-Manley units were in operation.



Row of 25 Holmes-Manley units in a Gulf Coast refinery. Note stacks of De Florez heaters which replaced early box type heaters.

As far back as 1913 Roy and Walter M. Cross, operators of the Kansas City Testing Laboratory, at Kansas City, Missouri, had been experimenting with cracking processes. They believed that cracking could be safely and satisfactorily accomplished at a pressure of 600 lbs. and higher, and with temperatures as high as 900 deg. F. After several tests had proven the soundness and practicability of their theories a small commercial plant was built and thoroughly tested with results which fully convinced all who saw it of the value of the process to the refining industry. Roy and Walter M. Cross had begun their experiments as scientists. They were not refiners and it therefore became necessary for them to develop some means of inducing refiners to install units for using their process and also some method of licensing such refiners. The Gasoline Products Company, Incorporated, was formed to promote the licensing of the Cross cracking process and later The M. W. Kellogg Company was appointed licensing agent to design and erect the cracking equipment licensed under the Cross patents. As the process became more widely used its popularity increased and the licensing and engineering organization which had been organized to handle its licensing matters became a most important factor in organizing cooperative research and development work in the oil industry and the dissemination of information of value to licensees.

With the cracking art making the rapid progress that it did during the ten or twelve years immediately following Burton's first experiment and with new processes and improvements of all sort being developed, it was perhaps only natural that the patent situation soon became exceedingly complex, so complex indeed, that few within the oil industry could determine or evaluate the legal status of the different available processes. The close relation of the various processes to one another and the fact that certain features were common to many of them could not be denied. It became evident to those concerned that patent conflicts



Six Cross units built in 1927 showing changes in furnace design and increased output. Each of these units would produce about 700 bbl. of cracked gasoline per day.

would have to be eliminated by some sort of cross licensing arrangements between the various companies if any of them were to be able to operate, and to license others to operate, under their own cracking patents without risk of expensive litigation and hazard of claims for substantial damages. As long as such patent conflicts existed, there could not have been any cooperation as to research and development between the various companies using and licensing their cracking processes.

The first major step towards clearing up these patent conflicts came in 1921 when an exchange of licenses between Standard Oil Company (Indiana) and The Texas Company was effected. About two years later The Texas Company made a cross-licensing agreement with Gasoline Products Company, Inc., and shortly afterwards Standard Oil Company (Indiana) and Standard Oil Company of New Jersey concluded cross-licensing agreements with The Texas and Gasoline Products. An exchange of all cracking patent rights severally owned was thus agreed upon and all the signatories to the agreements and their licensees obtained much more freedom for the operation of their individual processes. The operating freedom of this group and of their licensees —and through it the refining industry as a whole—was further improved by the later securing of licensing rights under patents of other large refiners, amongst them being the Gulf Refining Company, Atlantic Refining Company, Sinclair Refining Company, and the Anglo-Persian (now Anglo-Iranian) Oil Company.

Although the agreements between the companies forming this group allowed them full latitude insofar as the granting of licenses for their own processes went, Gasoline Products Company became the most active licensor of the group and so became a clearing house of information on cracking research and development.

The licensing activities of Gasoline Products Company necessitated a medium being set up for fundamental research and the developing of operating improvements which could be embodied in the commercial designs provided for use by the industry. In the earlier days of cracking such work had been limited and somewhat hindered by the uncertainties of the patent situation. In 1931, however, a research program on pyrolytic cracking was initiated by Gasoline Products Company, and the necessary organization set up for the correlation of commercial operating experiences of The Texas Company and Standard Oil Company (Indiana), as well as the laboratory research in this field being carried on by both of these companies. The M. W. Kellogg Company, engineers and contractors, as licensing agents of Gasoline Products Company were in position to translate the developments of this group into commercial designs for the industry. The organization for the bringing together and correlation of research and operating data was termed the Cracking Development Conference. Later, the Standard Oil Development Company entered the Conference, adding to the wide scope of commercial operating data and a well balanced laboratory research program available to the Conference for the benefit of licensees of Gasoline Products Company.

The Conference has now been in existence for seven years, during which the use of cracking has increased almost 50 percent, and the technique has markedly changed. It is interesting to observe the parallel between the work of the Conference and actual commercial improvements, which have not been limited to Gasoline Products Company licensees, but reflected by the whole industry.

The work of the Cracking Development Conference has generally been divided into three fields, namely, Research, Engineering and Design, and Operations. These fields generally involve different origins of particular developments, as well as different types of effort and personnel, in the stages leading up to the reduction to commercial or general use. Whatever the origin of a project, the development stage includes the obtaining, analysis and correlation of available data, usually presented in written reports which are submitted for study to the engineers and chemists in the Conference membership. After such study the entire subject can be presented in a meeting of the entire Conference membership in which agreement is reached as to the commercial possibilities or other aspects of the question. The business of the Conference is rather wide in scope and each of its divisions is interesting to consider in some detail.

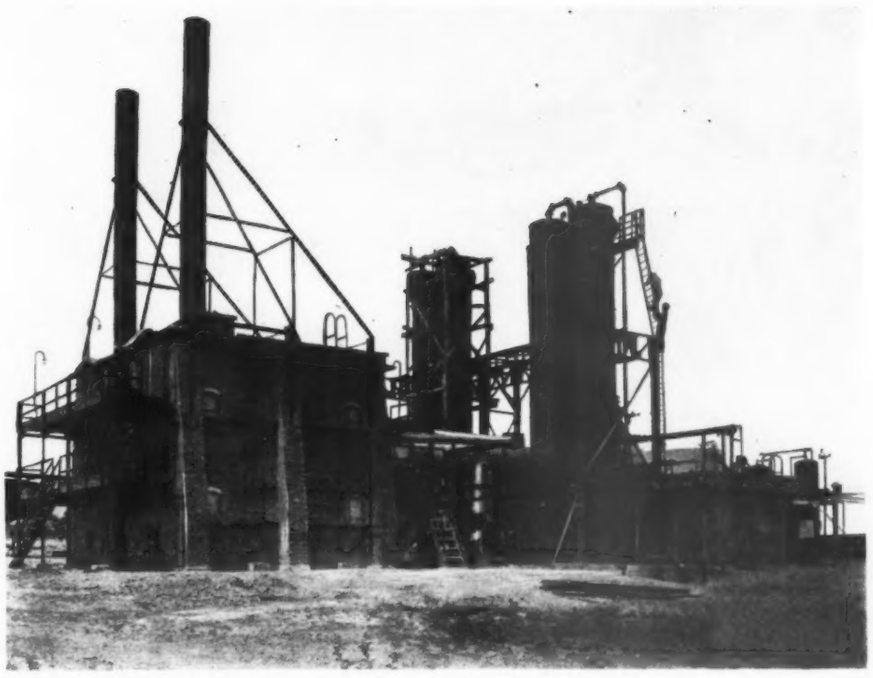
The division of activities termed "Research" generally embraces investigation of more or less fundamental nature directed at the basic factors which govern the cracking operation as a whole. This division includes, for example, all determinations of physical properties of hydrocarbons which form the basis of design, and the investigation and evaluation of the effect of all variables on a given type of cracking reaction. Under this heading has also come analytical cracking tests for the purpose of determining the best method of handling and possible products from new feed stocks, these being in essence, pilot plant duplication of commercial operations.

Most of the work in the research division has been in the laboratory, on small cracking units or other equipment, a necessary requirement in fundamental and analytical work for which commercial equipment is generally not practical. The development of laboratory apparatus for reliable duplication of plant-scale operations and results has been a difficult problem with solution made possible only through years of experience of the cracking research organizations of Standard Oil Company (Indiana), The Texas Company, Standard Oil Develop-

ment Company, and The M. W. Kellogg Company. Small scale equipment has been required for such diversified operations as reforming, coil-only cracking, coil and drum cracking, and the so-called de Florez and Indiana types of coking, as well as for the investigation of special phases of certain operations, and in all of these accuracy and commercial reproductibility is a common requirement.

In such small apparatus heat losses are an important factor and means had to be worked out for their control and for making parts of the equipment substantially adiabatic. Heating through accurately regulated temperature gradients and with controlled heat densities have required much study and experimental work and efficient types of lead pot and other heaters have been developed which are adaptable to almost any requirements. The deposition of coke within small scale systems is of even greater importance than on plant apparatus and this has required much development work in its alleviation. Problems of control of pressures, temperatures, and levels have required very accurate apparatus and although it has been sometimes possible to use commercial plant-scale instruments, new types of valves, floats, and other apparatus have been required in many cases. Likewise, reaction time relationships, fractionation apparatus, sampling technique, and other features have required adapting to small-scale equipment. The wide diversity of processes licensed by Gasoline Products Company has greatly broadened the scope of laboratory work. Laboratory research work has been conducted both in the Gasoline Products Company's laboratory by personnel of The M. W. Kellogg Company and in those of the several member-companies. The Gasoline Products Company laboratory has been devoted to more general problems, while the operating companies were concerned with problems involved with their individual operations. Typical major problems on which research programs have been completed include the following:

Combination Cracking Feed Stocks to Liquid Residuums.
Combination Cracking Feed Stocks to Coke.
Naphtha Reforming.
Viscosity Breaking, Including Criteria, Permissible Extent, and Comparative Merits of Single Pass, Multiple Pass, and Recycling.
Uni-Coil Cracking.
Permissible Heat Densities in Cracking Coils as Related to Rate and Extent of Cracking.
Reaction Velocity Constants on Fresh and Cycle Stocks.
Thermal Properties of Liquid and Vapor Hydrocarbons.



Two early type Cross units built in an Oklahoma refinery in 1923. Total capacity of both units was 450 bbl. per day of cracked gasoline, which gave rise to the necessity for installing large numbers of units in one refinery —26 such units were installed in 1924.

Hydrocarbon Phenomena in the Region of the Critical.

The correlated research work conducted by the several laboratories has yielded much valuable data on the fundamentals influencing cracking unit gasoline yield, octane number, and residuum properties which have pointed the way to an increased recovery of the highest quality products. It has likewise formed the basis for the involved combination type operations and their investment economies.

In the field of "Engineering and Design" the objective of the Cracking Development Conference work is to correlate the information gathered through the channels of "Research" or "Operations" and to handle all matters of a mechanical or structural nature from the standpoint of use in commercial design. This division is concerned with both the processing and equipment, and even covers certain aspects of maintenance and repair work because of their relation to general cracking plant engineering and design.

It is equally important to the refiner that his apparatus, from the process standpoint, be properly suited to its required duties and, from the equipment standpoint, be constructed so as to withstand both the ordinary wear and tear of operation and have resistance to the corrosiveness of the oils under treatment. The wide facilities of the Conference have, therefore, been devoted to the correlation of data on all phases of equipment performance and permissible capacities insofar as they bear on design, as well as materials and construction methods. In the engineering and design division, reports are periodically submitted covering individual experiences, materials, etc., and opportunity is frequently offered to compare the detailed design of a new cracking unit with its actual commercial performance. Such reports are studied by the Conference membership, along with data obtained under the headings of "Research" and "Operation" and after correlation are finally presented for discussion in a general meeting of the membership to bring out whatever generalizations are possible.

Typical examples of the subject matter handled under the head of "Engineering and Design" are shown in the following subjects which have been studied in detail by the Conference:

Fundamental Factors Influencing High Pressure Fractionating Tower Capacity.
Heat Absorption Rates in de Florez and Box-Type Furnaces.
Corrosion Protective Liners, Refractory and Alloy.
Welding Chrome Alloys.
Furnace Header Design and Specifications.
Cracking Unit Safety Inspection Methods.
Design and Performance of a 1500-Bbl. Unit for Combination Cracking Mid Continent Reduced Crude.
Design and Performance of a 25,000-Bbl.

Details of modern refineries: on the right is shown a small part of the great Richfield refinery at Watson, California which has a capacity of 66,000 bbl. per day in two combination units.

Photo by Robert Yarnall Richie

Unit for Complete Processing of Mid Continent Crude to Fuel Oil and/or Coke.
Design and Performance of a 12,000-Bbl. Unit for Reforming Iranian Naphtha.

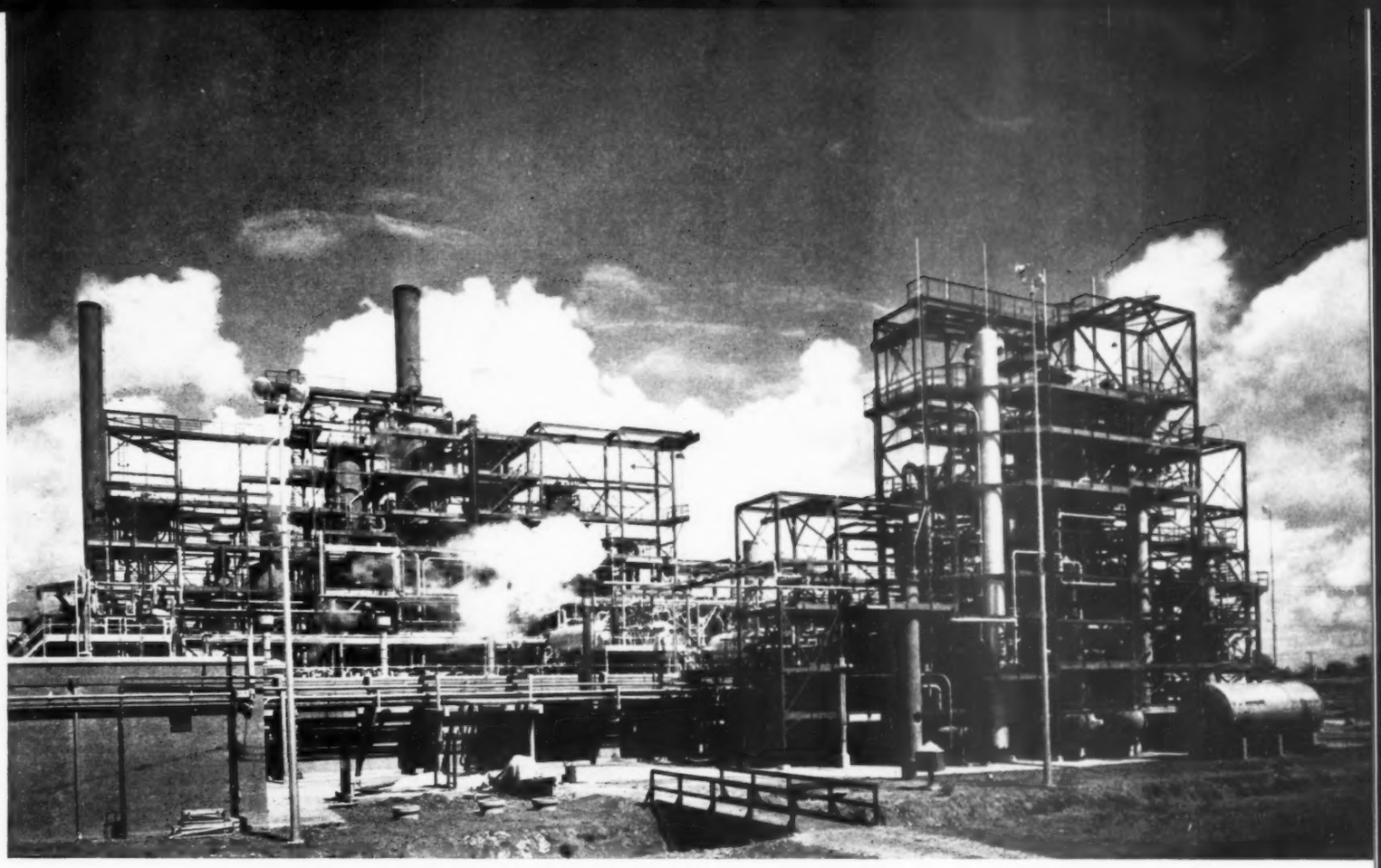
The division of "Operations" embraces the field of actual commercial results. The final proving ground of all new processing and materials is actual operation. In addition, a certain amount of plant-scale experimental work is continually under way, aimed at the improvement of capacity, yields, or quality of products, from existing apparatus. The results of such experimental work must be analyzed and correlated for their more general applications. Economic studies are usually under way for determining the most profitable manner in which to operate specific types of equipment. The performance of new plants requires observation and analysis to make their results available for engineering and design purposes.

The work of the "Operations" division includes following the numerous types of cracking operations, including Combination, Cross, de Florez, Holmes-Manley, Reforming, and others, not only with respect to the operation as a whole, but particular pieces of equipment or phases such as furnaces, soakers, corrosion and corrosion protection, etc. While the Combination Process is predominating in the new construction, study of the older types of operation continues because it embodies many features of the other processes, and study of all is valuable, not only for existing operations, but for new design as well. Consideration is also given to general operating points such as coke deposition, and its elimination, limitations to operating time, effect of charging stock character on permissible cracking conditions, and to comparison of different commercial processing methods on various stocks. Typical examples of subjects studied under this heading are:

Operating of a 36,000-Bbl. Per Day Unit for Complete Processing of East Texas Crude.
Continuous Coking of Mid Continent Crude.
Operations of a 1,500-Bbl. Combination Unit Processing Lea County, New Mexico Crude.
Desalting Refinery Charging Stocks.
Decoking Heater Tubes with Steam and Air.
Criteria of Suitability of Charging Stocks and Specific Operating Conditions.

The developments originated by the Cracking Development Conference are made available to the refining industry through several channels. The principal channel is through embodiment in designs of new units built by The M. W. Kellogg Company which supplies the personnel for the Gasoline Products Company research and which as a member of the Conference is continuously in touch with all of the developments within the organization. The large amount of basic information made available to this engineering organization through the Conference, as well as the constant contact with the operating end of the industry which is provided, has enabled advanced designs of cracking equipment to be offered to the industry through the Kellogg Company, as has been witnessed in the wide use of Combination Cracking Units which were pioneered by them. The other principal channel through which the Conference makes its developments available to the industry is through the process division of Gasoline Products Company. Through this staff, consultation is offered refiners on their processing and engineering problems. Under this arrangement assistance is provided in connection with the revamping and modernization of old cracking equipment, the study of economical methods of processing including providing processing information in cases of new design. Consultation service on the subject of safety inspection is also provided.

In addition to the services provided to Gasoline Products Company licensees, certain fundamental information which is useful to the industry as a whole is published in the technical literature. Such publications have included the results of experimental work on cracking reaction velocity constants, naphtha reforming correlations, total heat data on the hydrocarbons and many other subjects. The research work upon which this published data was based was undertaken to supply a particular need within the Cracking Development Conference group and it is reasonable to assume that the industry as a whole has benefited from a greater



View of a large modern refinery in Texas belonging to the Atlantic Refining Company. Photo by Robert Yarnall Richie

knowledge of the fundamentals of cracking unit design which these publications have made available.

It is interesting to consider the degree to which the industry has benefited from many developments which the Cracking Development Conference organization has assisted in working out. A comparison of pyrolytic cracking technique of 1938 with that of ten years ago reveals a great change not only in the process but in equipment and products as well.

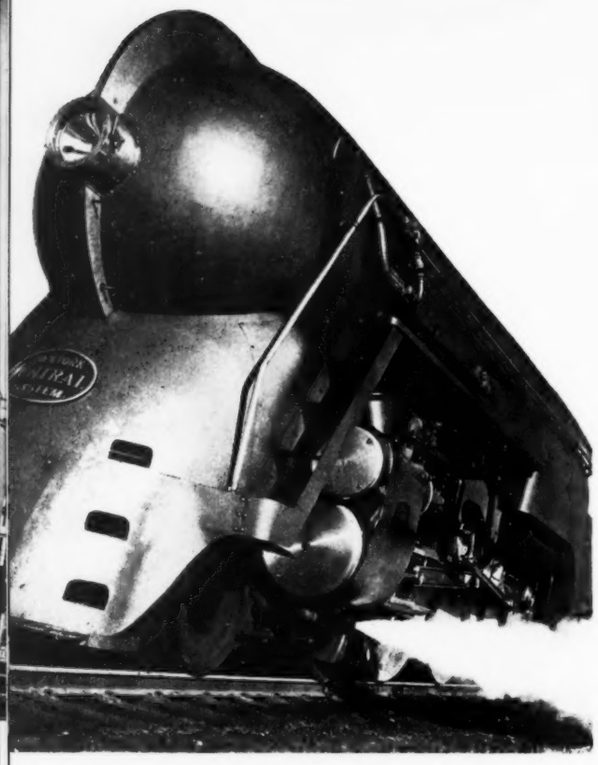
Possibly the most marked change has been in the adoption of combination crude and cracking units which take the place of the former separate installations for these purposes, which necessarily required intermediate tankage and much accessory apparatus. Combination cracking units, including all crude distillation, viscosity breaking, high temperature cracking, etc., have dominated recent refinery construction and some units include additional integrated operations such as Gray treating and gas polymerization. This type of unit has opened a new era of refinery construction to large and small refiner alike, and much effort has been devoted by the Cracking Development Conference to their development since the first large multi-function unit in 1932 demonstrated the important possibilities which had previously been realized only partially.

It is now within the power of every refiner to make gasoline of a wide range of octane number, and choice is mainly dependent on economics. This is attributable to both the possibilities of naphtha reforming and the adaption of cracking processing so that the higher temperatures necessary for anti-knock properties can be employed for the production of the bulk of the gasoline.

Refiners have benefited also through increased understanding of the mechanism of coke deposition, including its relation to heater feed stocks, digest times, extent of cracking, etc. so that limitations to length of run from this cause have been greatly reduced. While the length of run of typical cracking equipment of ten years ago was limited to a few days, it is now not unusual to find Combination Units running on schedules of four shutdowns per year. This means greatly decreased repair and maintenance costs, as well as maximum output from the invested capital. Closely related to this feature is corrosion prevention. The use of alloys has resulted in economy of material and decreased shutdowns and repair costs. Development of means for protecting existing vessels and other equipment with alloy and refractory liners have resulted in a tremendous saving in corrosion costs. Because of corrosion protective methods developed and studied within the Cracking Development Conference group, cracking equipment over ten years old is still in operation in 1938 with substantially its original thickness practically unimpaired.

The many improvements made in old cracking processes, the many new refinery processes developed and the many other advances made in refinery equipment since the Cracking Development Conference was organized have helped materially in conserving the nation's oil resources. When cracking was first gaining a commercial footing in the United States, each barrel of crude processed yielded approximately eight gallons of gasoline while in 1936 the recovery averaged 18.6 gal. per barrel, resulting in the yearly saving of around 1,000,000,000 bbl. of crude.

In summary, the result of this progress in the pyrolytic cracking art has been the more economical use of natural petroleum resources and the providing of a vastly superior gasoline to the motoring public in 1938 at a service station price (ex tax) of about two-thirds the 1923 cost. This would not have been possible but for the cooperative effort of the far-seeing refiners and others who removed patent barriers and combined their experiences and research facilities, and by so doing made available to refiners everywhere the most modern refining processes.



REFINING TECHNOLOGY

To Be Influenced by General Trends

By Dr. O. W. Willcox

Direction to Be Followed in Developing New Techniques of Refining Is Determined by Economic and Legislative Trends As Well As in the Research Laboratory.

WHATEVER may be the momentary dissatisfaction a petroleum refiner may at times feel about his particular branch of the oil business, there is one solid fact in which he can take comfort: the petroleum industry is essentially a depression-proof industry, as indicated in the accompanying table.

Comparative Progress of Steel, Gasoline and Groceries

Year	Gasoline Consumption in million gallons	Ingot Steel production tons	Grocery Chain store index
1929	14,677	56.4	100
1930	15,786	40.7	98
1931	16,621	25.9	93.8
1932	15,500	13.7	83.4
1933	15,438	23.3	78.1
1934	16,587	26.1	81.0
1935	17,716	34.1	87.1
1936	19,565	47.8	91.7
1937	21,146	49.5	93.0

Three years after the crash of 1929 the steel industry, which is accepted as a principal barometer of business activity in the United States, had lost three-fourths of its former business. By 1937 steel production had rebounded to about 87 percent of the 1929 volume; then along came the second depression in the fall of 1937, and if the figures for the first seven months of 1938 are a reliable forecast, this year will see a steel ingot production of only 12,800,000 tons, which is lower even than in the disastrous year 1932.

At the same time the business index of the grocery chain stores, which reflects with fair accuracy the current purchasing power of the general public, also started on a decline. By 1933 the grocery chains had lost practically a fourth of their business; then a gradual improvement set in and by 1937 the index had reached 93 percent of the 1929 index; the second depression came on, and from the records of the first half of 1938 it appears that this index will show a marked setback. During the same period all the other more important business indexes—car loadings, building, employment, etc.—showed similar declines, partial recoveries and fresh debacles.

Meanwhile the production and consumption of gasoline kept right on growing. Every year since 1929 the gasoline consumption figures show a steady increase; the drop of 68 million gallons between 1932 and 1933 hardly counts as an interruption in this constant upswing. And if the A.P.I. figures of gasoline consumption for the first six months of this year afford a safe basis for prediction, the record of 1938 will stand at 21,600,000,000 gal. In other words, the new depression which began in 1937 and which again pulled down the rising curves of all other business indexes, did not halt the upswing of gasoline consumption.

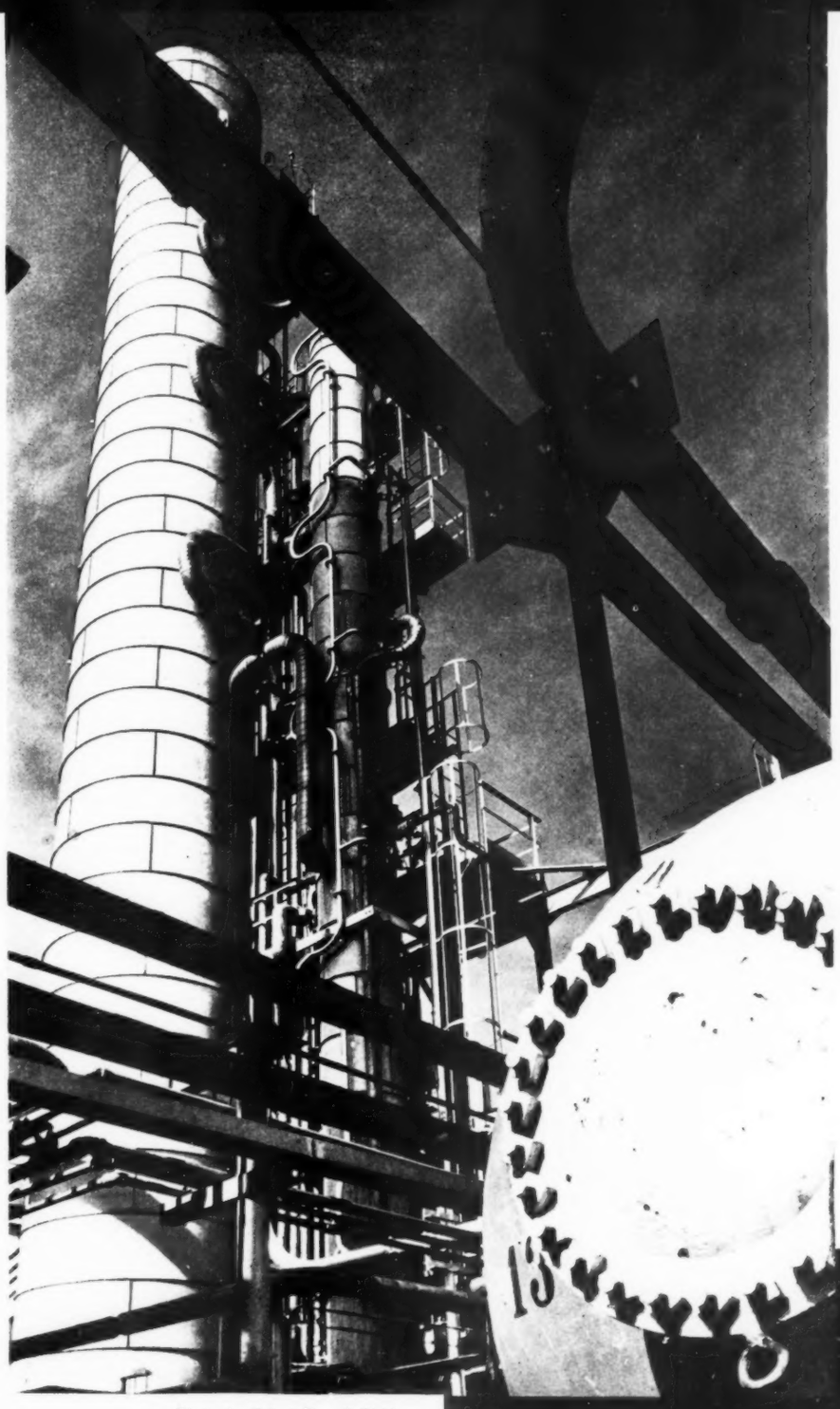
So, in so far as the oil business depends on the market for automotive fuel (as it mostly does) it can be regarded as essentially depression-proof. The oil refiner, and with him all other members of the petroleum industry, can feel assured that their occupation will not be taken from them nor even seriously diminished in importance by recurrent economic storms. The events of the past ten years have luminously demonstrated that gasoline is a commodity that is literally indispensable. People may curtail their consumption of steel, they may stint themselves on food, they may defer the erection of needed housing and in other ways accommodate themselves to lower incomes, but they keep on buying more and more gasoline.

It may appear somewhat singular that while the volume of gasoline thus increases the production of new automobiles should show a severe decline. But this is merely a sign that the automobile industry itself is not depression-proof; old cars are kept longer in service, and for reasons of thrift people are denying themselves—temporarily at least—the luxury of new vehicles.

The oil refiner can therefore make his calculations for the future on the basis of a permanent and to all appearances a constantly increasing demand for his main products—gasoline and motor oils. The demand for secondary products such as fuel oil and lubricants for general industry may rise or fall with the turns of the business cycle, but gasoline sales seem destined to go on increasing indefinitely, so far as anyone can now foresee. The automobile industry will undoubtedly come out of the doldrums; the chief of the U.S. Division of Public Roads has announced that surveys made by his Division indicate that present traffic on the nation's highways will be doubled by 1960 and that the mileage of roads now carrying 2,000 or more vehicles daily will then be serving at least 4,000 vehicles. The official who made this prophecy may have had an eye to securing larger appropriations for road building, but his forecast may prove approximately true.

Besides the well grounded assurance that gasoline consumption by road vehicles will never become less and will almost certainly swell in constantly increasing volume during an indefinitely long future, the oil refiner can look forward to an increase in airplane transportation. It is true that from the volume standpoint the consumption of petroleum products in civil aviation in the United States is at present relatively insignificant. In 1937 the gasoline requirement of commercial and private airplanes in this country was a mere 52,000,000 gal., or no more than 0.2 percent of the total gasoline consumption of the whole United States; lubricating oil consumption by civil airplanes was about 1,000,000 gal., amounting to only 0.1 percent of all lubricating oil sales. Even with the addition of 37,600,000 gal. of gasoline and 1,160,000 gal. of lubricating oils used in military machines the part played by American aviation as an outlet for petroleum products is still small—less than 0.5 percent of total demand for gasoline and less than 0.3 percent in total demand for lubricants.

However, the airplane undoubtedly has a great future before it. Air traffic is now only at the stage reached by road automotive transport 25 years ago. What it will



Photos by Robert Yarnall Richie

Opposite, oil burning locomotive a new market for oil products; above, Paulsboro refinery of Socony-Vacuum; right part of a modern polymerization plant,

be 25 years from now no one can surely say, except that it is bound to grow.

While the demand for gasoline for road transport is certain to increase, and a large expansion in aviation requirements is more than probable, increasing demands on oil production and refining capacity are equally certain to arise from other quarters. Among these, of course, is the growing use of the Diesel engine. This development, which apparently has now merely well begun, is important to the refiner because it is capable of absorbing products which for one reason or another it is not convenient or desirable to transform into higher priced goods.

To the general public the Diesel engine holds out the possibility of reduced transportation costs. It has achieved spectacular prominence in marine traffic and in streamlined trains for fast passenger service on the railroads. Less spectacular but of far greater importance to the oil industry is the spread of the Diesel engine in general industry, and for powering busses, tractors, trucks, etc. Significant of the coming development is the announced intention of large manufacturers to begin mass production of Diesel units suitable for small manufacturing concerns and general farm use.

The economic appeal of the Diesel engine lies not so much in the fact that it consumes a cheaper fuel, but because it gets more work out of that fuel than any other prime mover; six gallons of Diesel oil will do as much as 10 gal. of gasoline under the same operating conditions. One tank car (8,000 gal.) of Diesel oil is said to be the equivalent of 12 carloads (660 tons) of coal in switching service on a railroad, from which it can be figured that one gallon of Diesel oil is the equivalent of 120 lbs. of coal in such work. For this reason the railroads are beginning to take as much interest in Diesel powered switching and freight engines as in Diesel powered passenger engines.

It has been calculated that the Class One railroads of the United States could save 75 percent of their switching fuel expense by replacing coal-fired locomotives in this service by Diesel powered switching en-

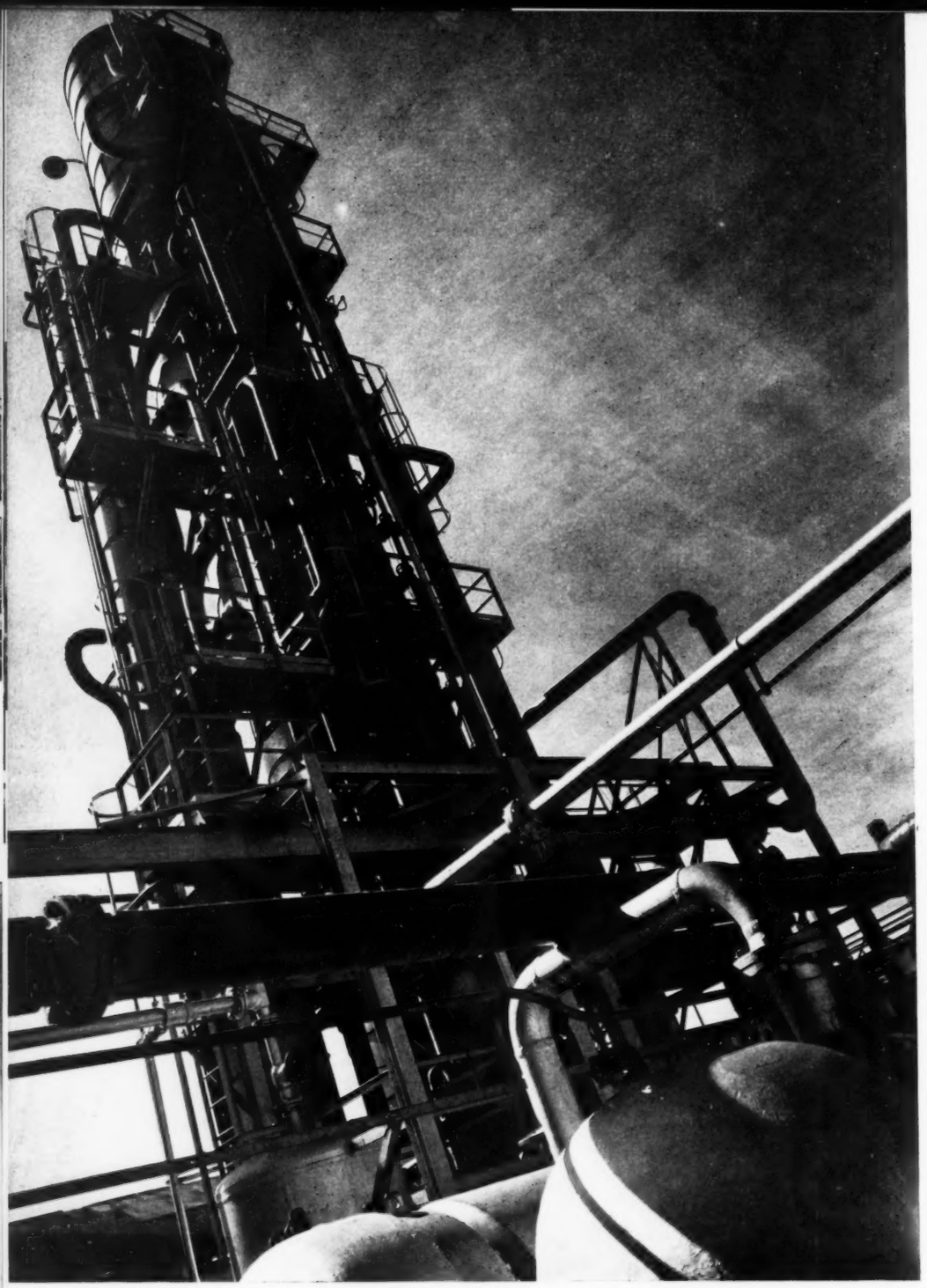


Photo by Robert Yarnall Richie

Another view of the Socony-Vacuum Oil Company's refinery at Paulsboro, N. J.

gines, not to mention substantial economies in maintenance. A number of prominent railroads have proved the fact by experience. This switching experience has paved the way for extension of Diesel-electric locomotives to fast freight service and branch line operation. Consumption of Diesel oil by railroads in 1937 was double that of 1936, and the future is bound to show an acceleration of the movement.

Somewhat farther off is the extension of Diesel engine to the passenger automobile and the airplane. Here the underlying motive, as in other applications of the Diesel engine, is the saving in fuel costs, but there are two difficulties that have yet to be overcome. The most important of these difficulties is the present higher cost of the Diesel engine as compared with the gasoline engine. Where an automobile owner drives his car an average of 20,000 miles a year (and few drive as much as this) it would be five years before the saving in fuel would equal the larger cost of the Diesel engine. This objection does not hold to the same extent in the case of trucks and busses, or as to large industrial engines that are kept in practically constant use. However, the disparity in cost may yet be abolished by mass production and improvements in design. As for use of the Diesel engine in aviation, the factor of weight is a large handicap, which also may disappear as a result of improvements in construction. Even so, future application of the Diesel engine in automobiles and airplanes may be further retarded, if not prevented, by the present tendency toward higher octane ratings of gasoline; the efficiency of aviation engines using 100-octane gasoline is now such that airplane designers have for the time being practically abandoned serious study of the Diesel for this use.

In summarizing the directions from which the oil refiner may expect an increasing demand for his products we come next to burners for domestic heating. Increase in the demand for fuel oil for general industrial use in substitution for coal (as in railroad services and manufacturing) is not excluded. This outlet is large and may be expected to expand with every improvement in business conditions, but it may also be expected to contract with every economic slump. In other words, the business of supplying fuel oil for general purposes is not as depression-proof as the trade in gasoline and lubricants for automobiles and airplanes. On the other hand, every year has shown a notable increase in the number of installations of oil burners for heating and other domestic purposes, and as the number of such units grows the petroleum industry is assured of a permanent outlet for burner oil. This demand once aroused, will be stable for much the same reason that the demand for gasoline does not diminish—comfort, convenience and cleanliness, for which the average householder is even willing to pay a premium over the cost of heating by solid fuel. The expansion of burner sales of course is affected by business conditions, but it is to be noted that when such units have once been installed in a period of prosperity they continue in operation during depressions.

Thus far, our attention has been centered on what may be considered the positive or encouraging aspects of the oil business in general and the refining industry in particular. It amounts to this: the petroleum industry has before it the prospect of an expanding business in a seemingly indestructible market. An appraisal of the present position and conceivable future of the industry would in a measure be incomplete without some consideration of certain more or less visible contingencies.

One of these contingencies relates to the future supply of crude petroleum. There

are two possibilities. Either the discovery of new oil fields will continue at a rate that will at least keep up with the constantly increasing rate of consumption, or new production will not compensate the depletion of existing reserves. In the former case the present situation will hardly be changed; in the latter case the oil business will enter a scarcity phase; prices must rise, and the skill and ingenuity of the refiner will be put to the test of making a dwindling supply go as far as possible. New and better processes and more efficient equipment and methods will be needed; supplies of materials not now regarded as economic will be drawn upon, and oil production and refining will become more than ever an indispensable factor in the national economy. At present the rate of consumption is tending to outstrip the rate of new discovery. It has been calculated that the scarcity phase will begin to materialize about 1942. Those responsible for this conclusion are absolutely right if the rate of discovery does not accelerate, but as has happened so often in the past the drillers for oil may upset their calculations. On the whole, there is little prospect that the oil refining industry will soon suffer any material curtailment on account of difficulties in obtaining supplies of raw material.

Another circumstance that may be taken into consideration in estimating the future of the petroleum industry is the probable course of fiscal legislation. It is no news to mention the fact that petroleum products, especially gasoline, bear what may well be described as a heavy load of taxation. In many states what the motorist pays to the tax gatherer equals and frequently exceeds what he pays to the oil refiner. It will also surprise few competent observers to suggest that the tax gatherers have not yet reached the limit of their exactions; local, state and national budgets have grown to enormous proportions; eventually these budgets, now resting largely on pyramids of debt, must be put on something like a cash basis, and the petroleum industry has demonstrated only too well that it is a rich source of tax money; it is now, in fact, the largest single tax payer in the United States. Originally, gasoline was the principal target of the tax legislators, largely for the purpose of constructing roads on which motorists could burn more gasoline. Then gasoline was called on to contribute increasingly to general revenues, which it has done (from the tax collector's standpoint) handsomely. Other oil products, as lubricating oils, were laid under mild contributions which have increased with time and are still increasing. Even fuel oil, which for long was overlooked, has been found by some states to have excellent tax-yielding possibilities.

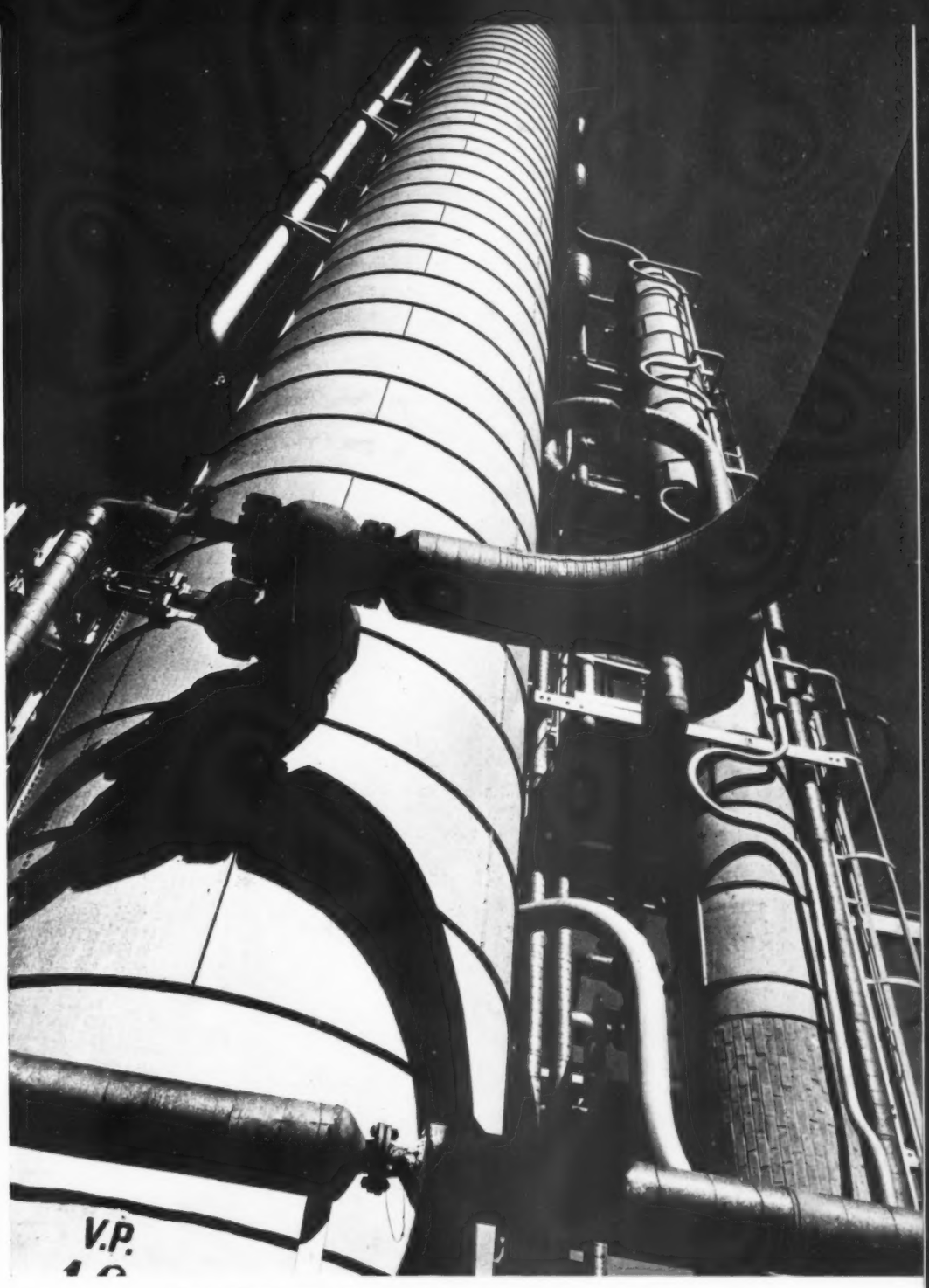


Photo by Robert Yarnall Richie

Looking up the massive towers of a modern refinery.

It is not the writer's purpose to present arguments for or against oil taxation. We are here taking for granted the cold fact that the oil industry is now supporting a large load of taxes and is likely to find this load becoming heavier. This being the case, the question of immediate interest is: supposing that the trend toward higher oil taxes cannot be stopped, what effect will this trend have on the future of the petroleum industry?

In considering this question we have before us the fact that the American market for the main products of the petroleum industry—gasoline, motor oil and to a certain extent other products—has heretofore shown itself to be practically indestructible. During the severest and most prolonged business depression the United States has ever known, the consumption of gasoline has grown at an accelerating rate, even in the face of heavy taxation. Obviously, an extensive reduction of the buying power of the general public, plus onerous consumption taxes, have not prevented the industry from expanding its

sales from year to year; profits have been diminished but by no means extinguished, and even the enthusiasm of adventurous wildcatters has been little dampened.

The indestructibility of the gasoline market is of course not absolute. It is conceivable that taxation may become too great to be wholly passed on to the consumer, and the curve of gasoline consumption, now vigorously rising, may be forced downward. However, until the point is actually reached where gasoline consumers refuse to absorb new tax burdens the petroleum industry will have little real cause for alarm. That point has not yet been reached, and only experience will show where it really lies. Motorists in other countries seem to have an enormous capacity for taking tax punishment; the curve of gasoline consumption is rising even in some European countries where fiscal burdens on this commodity are three and four times as heavy as in the United States.

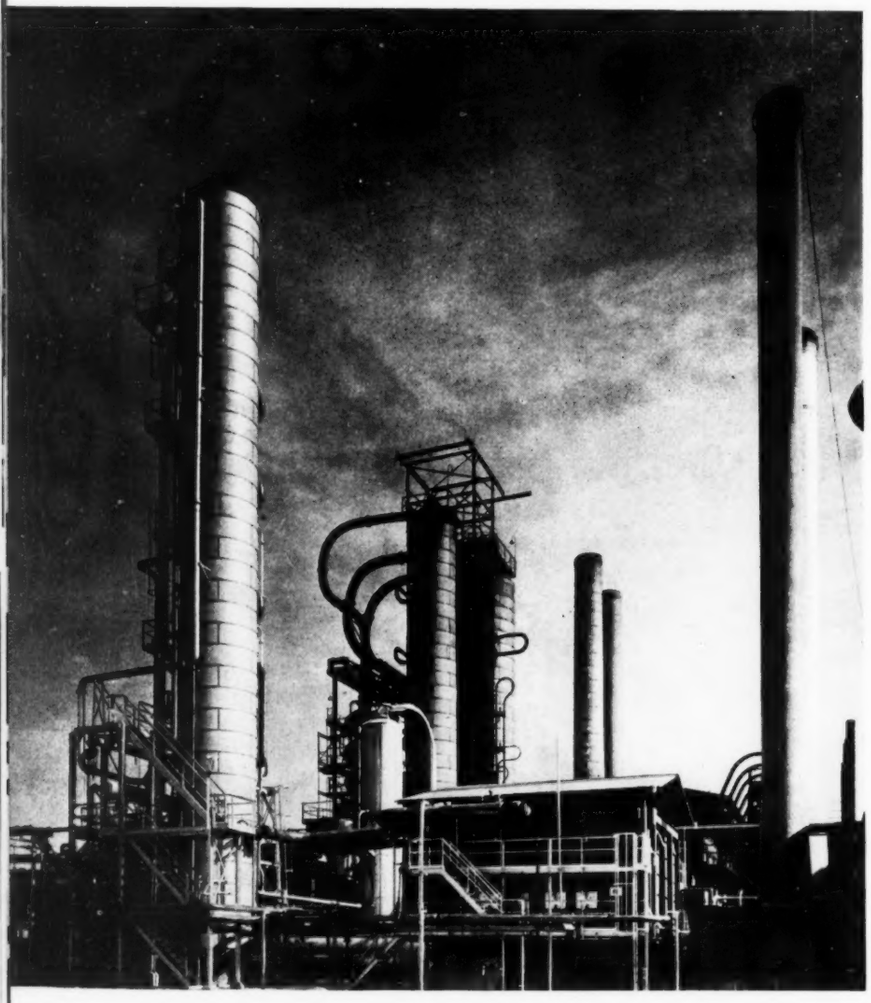
The factors that make gasoline a nearly indispensable article of use are convenience, comfort and speed; it is hard to express such values in terms of money, but their money equivalent is undoubtedly large; and the same in a measure applies to lubricating oil, without which machinery cannot be moved at all. On the other hand the cash value of certain strictly industrial oil products at the point of vanishing utility can be fairly accurately appraised. In the case of fuel oil, which has aroused the special enmity of the coal interests, engineers have calculated that with coal at an average price of $3.00 a ton, the price of fuel oil would have to rise to 23 cents a gallon before all the economy in the use of the Diesel engine would be exhausted. The grade of fuel used in Diesel locomotives now costs about 4½ cents a gallon. If the engineering calculation above referred to is even approximately valid, some rather severe taxation would be necessary to stem the drift to Diesels.

The disparity between the price which the oil refiners are willing to take for their products and what the consumers would be willing to pay if they are pushed to extremes is illustrated by the aviation industry's estimate of the utility of high-octane gasoline. According to some authorities (Egloff, Barnard) every extra octane number adds 2 to 5 cents to the earning power of a gallon of gasoline; one authority (Heron) states that under certain circumstances 100-octane gasoline may be worth $1.79 more in earning power than 87-octane gasoline.

The net conclusion from the foregoing considerations is that at least the immediate future of the petroleum industry is fairly safe from fiscal legislation that is not intentionally destructive; such legislation must be watched for and resolutely opposed.

In sum, the external situation of the petroleum industry is that of a business solidly based on a demand that is perhaps less susceptible to adverse influences and more immune to the inroads of substitutes than any other. Every enterprise within or related to this industry is assured of continued existence and even of growth provided it can keep abreast of the current of technological progress.

In such a highly competitive business as oil refining, a relatively low operating cost is the basic condition for economic survival. Within limits, costs decline as the scale of operations is increased; and as the scale of operations is increased the number of units necessary to meet the demand becomes smaller. How this principle is working out in the American oil refining industry may be inferred from the accompanying table showing the trend of oil refining capacity in the United States.



Trends in refining practice point toward a steadily increasing quality, higher yield of gasoline, and lower prices to consumers. The modern refinery shown on the left and the efficient natural gasoline plants shown opposite are typical of the refineries that have done much to conserve millions of barrels of crude oil in the United States.

Photo by Robert Yarnall Richie

Oil Refining Capacity in the United States

Year	Refineries Operating	Daily Capacity, Bbl.
1928	315	3,116,930
1929	341	3,454,250
1930	362	3,721,360
1931	397	3,913,180
1932	383	3,665,830
1933	424	3,696,410
1934	483	3,790,593
1935	496	3,815,470
1936	479	3,936,535
1937	471	4,038,010
1938	451	4,301,910

What may be read from this table is that the number of operating refineries reached a peak in 1935, and since then has shown a decrease while daily operating capacity has continued to increase and now stands at 4,301,910 bbl. This seems to indicate that in the future there will be fewer refineries but that they will be bigger ones.

Another and more unmistakable trend in oil refining is shown by the growth of cracking operations. Formerly, only straight-run gasoline was available and it still figures largely in the current supply, but since 1936 straight-run gasoline is being produced in smaller volume than the cracked product. This trend will undoubtedly continue, both on account of the octane superiority of cracked gasoline and on account of the economy of raw material offered by the cracking process. Crude oil

contains only a small proportion of distillate boiling within the gasoline range; cracking increases this proportion. It has been calculated that to produce all the gasoline consumed in the world during 1937 by straight-run distillation would have required more than 4,000,000,000 bbl. of crude oil, whereas only about 2,000,000,000 bbls. were actually used.

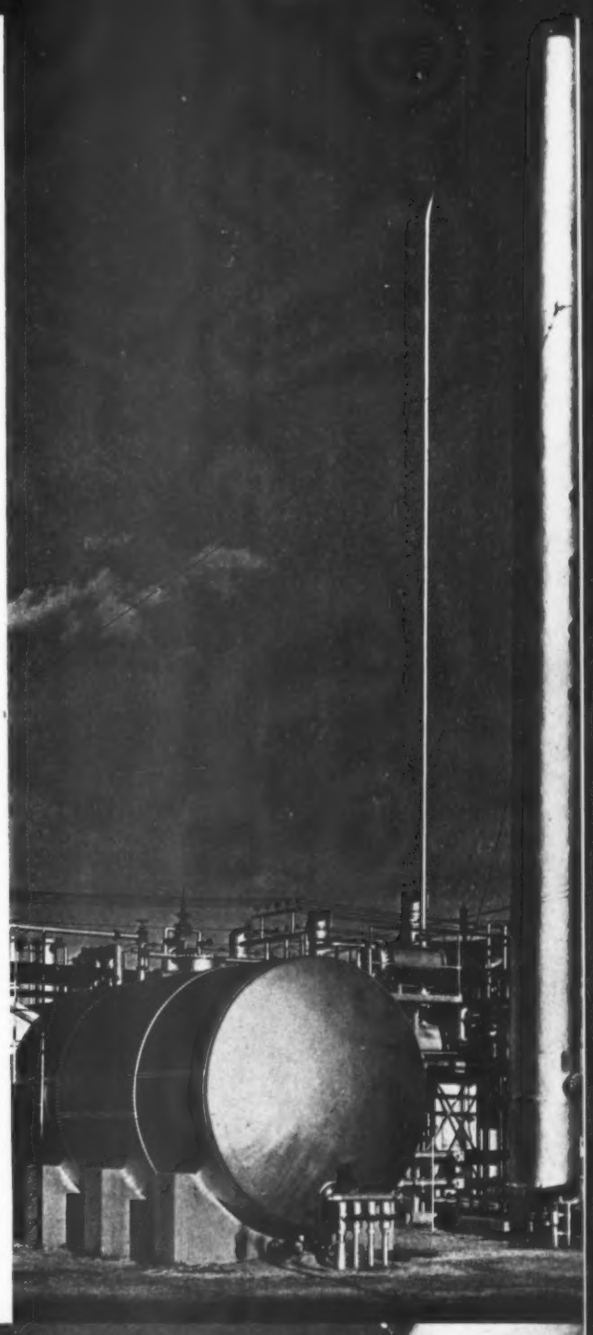
From the broad national-economic standpoint the invention and continued development of the oil cracking process is a notable technological achievement in true conservation of natural resources. When one barrel of crude oil is made to yield as much gasoline as two barrels the practical effect is to double the world's oil resources. The end of possibilities in this direction has not been reached. The best that the large modern combination-unit cracking plant can or is allowed to do is to convert about 68 percent of the crude oil feed into 70 octane motor fuel. That leaves 32 percent of the entering crude oil to be made into other products, generally of lower commercial value, such as fuel oil and asphalt, together with coke and incondensible gases which have no other use than as fuel. It is doubtful whether a much larger proportion of the crude can be made into gasoline, because a certain amount of lubricating oil must be produced, otherwise all machinery, including automobiles, must stop. But the oil refining industry will not have fulfilled its conserving mission until all its hydrocarbon material now going to coke or to waste gas has been converted to more valuable products.

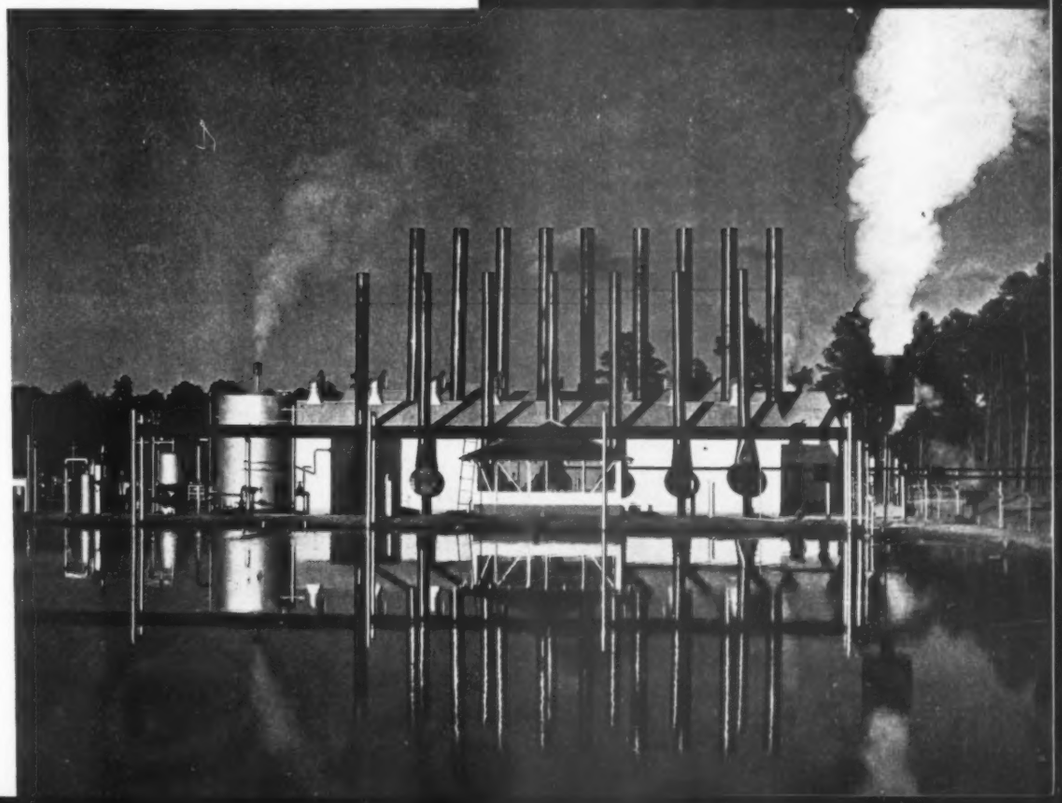
Besides the inevitable trend toward larger operating units for the sake of the economy these units afford, the refining industry has to face a remorseless trend toward higher octane values in its gasoline. It is not unreasonable to suppose that all gasoline of the future will approach if not reach 100-octane, but this trend is governed by factors outside the oil refineries. In the first place, the vast majority of existing automobiles do not require such high quality fuel; only 10 percent of the cars have been designed to run on 78-octane or higher gasoline, 60 percent require 70-octane or less and 30 percent will not knock on 65-octane gasoline. The market for high grade (premium) gasoline is therefore limited by this condition; it will expand in proportion as the designers of automobiles, strenuously competing among themselves for the favor of the public, increase the compression ratios of their engines to take advantage of the superior power residing in high quality fuel.

A brilliant future awaits high-octane fuel in the aviation industry, but here again the oil refiners will mark time while awaiting the development of outside circumstances; the market for aviation gasoline is exactly limited by the number of airplanes in service, and the number of passenger airplanes in service will grow only in proportion as the public becomes more air-minded; as has been remarked, the public will become air-minded in proportion as it is convinced of the safety of air transport.

Up to a certain point the oil refiners will experience no technical difficulty in meeting the demand for 100-octane or better gasoline. This point will be reached when the supply of C_3 and C_4 hydrocarbons, which are the present chief sources of this grade, begins to run short. Beyond this point the oil technologist must prepare himself to tear up the heavier petroleum molecules and piece them together again into new and useful patterns; as one writer puts it, oil products of the future will be more or less tailor made. This applies to lubricating oils as well as to gasolines. The meaning of this trend is that the business of oil refining must become more and more a complex art of decompositions, synthesis and rearrangements involving cracking, hydrogenation, dehydrogenation, polymerization, depolymerization, etc.

The oil refining art has become still more complex since it has been called upon to supply a host of products now also obtained from other sources. Petroleum is serving as a raw material for the production of long lines of alcohols, esters, ethers, acids, plastics, rubber substitutes, etc. But these side lines are more interesting than important; they absorb a very small proportion of the crude oil that flows from the wells. The main business of the petroleum industry now is, and will continue to be the production of fuel for internal combustion engines and lubricants for general purposes.





Photos by Robert Yarnall Richie

HOUDRY PROCESSES for Catalytic Treating of Petroleum

By Eugene Houdry, Houdry Process Corp. Wilbur Burt, Socony-Vacuum Oil Co. A. E. Pew Jr., Sun Oil Co. and W. A. Peters Jr., E. B. Badger & Sons Co.

This paper is being delivered at the Annual Meeting of the American Petroleum Institute, Chicago, Nov. 14-19.

THE purpose of this article is to present a general description of the present status of the Houdry catalytic processes in such detail as may be properly released at this time and within the space limitations required from a practical standpoint. Many specific engineering and technical details are purposely omitted to meet these limiting considerations.

The processes listed below constitute subject matter of 96 U. S. patents, not including corresponding foreign patents and pening U. S. and foreign applications.

The processes available under the Houdry Process Corporation patents and development may be summarized as follows:

(1) Catalytic cracking of a crude or any distillate fraction or residuum thereof, excepting straight run gasoline, for the production of gasoline, gas oils, furnace oils, with or without the production of tar or heavy liquid products.

(2) Catalytic vis breaking in liquid phase by which residues or tars may be reduced in viscosity to meet fuel specifications, without substantial production of gasoline.

(3) Catalytic treatment of gasoline from catalytic or thermal cracking.

(3a) Liquid phase catalytic treatment of aviation gasoline from catalytic cracking.

(4) Catalytic desulphurization of gases from cracking or topping operations.

(5) Catalytic polymerization in liquid phase of butenes.

(6) Production of light gravity gas oils for furnace oil requirements, or Diesel oils by catalytic cracking, charging heavier gravity gas oils or residuums.

The above operations were developed by Socony Vacuum and Sun Oil in conjunction with the Houdry Process Corporation and are controlled by the Houdry Process Corporation. Houdry Process Corporation is jointly owned by Socony Vacuum, Sun Oil and Eugene Houdry and his associates.

There are in operation at the present time three units, a gas oil catalytic cracker of 2,000 bbl. per day capacity at Socony's Paulsboro refinery, a 3,000 bbl. per day unit in a Socony European refinery and a 15,000 bbl. unit charging residuum at Sun Oil's Marcus Hook refinery. At the present time Sun Oil has under construction two large units and Socony an additional eight units. Units under construction will represent a $24,000,000 investment on the part of Socony and $11,000,000 by Sun Oil. The smallest unit under construction charges 10,000 bbl. per day to the catalyst and the largest 18,000 bbl. per day. Completion dates are scheduled for the midyear 1939. Some of these units are combination units with crude capacities as high as 28,000 bbl. per day.

Of the processes previously listed the most important is the cracking of crudes and fractions or residues thereof.

Diagrammatic flow sheet No. 1 shows the general steps used in processing a crude oil running to fuel oil, with one pass through the catalyst, and with straight run products removal optional. The dotted line indicates the flow if desired to run to no residuum. As shown in the flow diagram, crude oil is pumped through heat exchangers wherein it is preheated by the products from the catalytic cases, thence to a primary flash fractionating tower wherein the desired straight run products are fractionated and removed. The residue from the flash tower is pumped through a still, heated to approximately 880 deg. F., depending on stock, thence into a vaporizer. Tar bottoms are removed as a liquid and the vaporized fractions of the charge pass to the catalyst chambers. From the catalyst the vapors pass through the crude oil exchanger into the final fractionating tower wherein gasoline, furnace oil and heavy gas oil are separated, the latter two being combined, if desired, for recharge to catalytic or thermal cracking operations. If gas oil is charged, the flash tower and the vaporizer are eliminated, the charge being pumped through exchangers to the still and thence direct to the catalyst. If a residue is to be charged, the primary flash fractionating tower is eliminated, the charge passing direct to still and thence to vaporizer for tar separation. To eliminate fuel production the charge from the still is charged to a vaporizer wherein, through a special catalytic mass, the entire charge is vaporized and passed to the catalyst. In special cases it is advisable to charge the entire crude to the

TABLE No. 1

Yields and Product Charactistics Running Crudes and Residuums to Fuel—One Pass

Type Crude	East Texas		Grade B Coastal		36.6 °A.P.I. Mid Continent		West Texas		Mt. Pleasant		Lagunillas
	Topped of Str. Run Naptha	Topped of Naptha, Kerosene & Furnace Oil	Topped of Naptha	Running Entire Crude	Topped of Naptha	Topped of Naptha & Kerosene	Topped of Naptha	Topped of Naptha & Gas Oil	Topped of Naptha	Topped of Naptha, Kerosene & Gas Oil	Running Entire Crude
Chg. to Plant % Crude	58.5	38.0	75.6	100.0	66.7	52.4	68.5	35.0	62.0	43.3	100
Sulphur Content of chg. to plant	0.45	0.55	0.28	0.17	0.48	0.61	1.9	2.20	0.65	0.66	2.14
Tar, % Vol. of Crude	8.0	8.0	6.0	6.0	8.4	8.4	8.7	8.50	2.7	8.3	35.4
" A.P.I. Gr.	12.6	12.6	12.8	12.8	13.3	13.3	7.4	8.5	11.0	14.8	4.2
Chg. to Catalyst, % Vol. Cr.	50.5	30.0	69.6	94.0	58.3	44.0	59.8	26.5	59.3	35.0	64.6
" " " , API Gr.	59.0	33.9	26.8	31.9	30.0	27.7	27.0	20.5	31.5	27.2	25.2
" " " , I.B.P.	452	508	415	120	430	538	430	605	415	574	182
" " " , 50%	690	740	615	560	650	711	685	717	625	712	672
" " " , E.P.	760+	760+	760+	760+	760+	760+	760+	760+	760+	760+	760+
Dry Gas, % wt. chg. to Cat.	4.5	5.1	7.0	3.9	4.0	5.4	5.7	3.1	5.6	5.3	3.8
Catalyst Deposit, % wt. chg. to Cat.	5.3	5.4	4.4	3.4	3.9	3.5	5.3	4.5	5.2	4.9	4.5
Gasoline, % Vol. chg. to Cat.	44.0	42.6	47.2	60.6	41.9	44.1	45.3	39.1	40.2	47.0	44.5
" , A.P.I. Gr.	64.6	61.7	58.9	57.0	63.5	60.8	62.4	59.8	61.1	63.1	61.5
" , 50%	229	250	264	270	251	247	258	253	242	232	254
" , 90%	351	372	390	384	392	366	384	348	385	363	356
" , E.P.	401	412	429	425	440	413	424	397	424	416	396
" , R.V.P.	11.0#	10.0#	11.0#	11.0#	11.0#	11.0#	11.0#	10.0#	11.0#	11.0#	10.0#
" , Sulphur content %	0.03	0.05	0.02	0.02	0.06	0.06	0.14	0.23	0.03	0.04	0.13
" , Copper dish Gum	7	4	5	4	6	19	34	22	6	8	10
" , A.S.T.M. mm. Octane	78.8	78.8	78.6	73.8	76.8	78.4	77.6	81.0	77.0	79.4	77.7
Catalytic Gas Oil, % vol. chg. to Cat.	54.4	56.4	49.2	38.8	57.7	54.9	51.7	61.2	55.7	51.3	54.7
" " " , A.P.I. Gr.	29.5	26.9	26.0	26.3	30.8	28.6	26.2	20.2	33.1	26.5	22.7
" " " , I.B.P.	404	458	403	405	447	436	438	440	415	462	406
" " " , 50%	554	566	517	517	546	579	534	564	531	588	534
" " " , Pour point °F.	+45	+50	−10	−10	+30	+45	+10	+45	+10	+35	−(−60)
" " " , SU. Vis. at 100°F.	39	43	36	36	39	42	38	58	36	43	39
" " " , Sulphur Content %	0.24	0.31	0.11	0.11	0.20	0.21	1.06	1.04	0.14	0.29	1.17
" " " , Aniline Point °F.	134	142	125	127	140	140	134	130	135	124	95.7
Liquid Rec. % Vol. chg. to Cat.	98.4	99.0	96.4	99.4	99.6	99.0	97.0	100.3	95.9	98.3	99.2
Percent of 32° A.P.I. Gr. Furn. Oil in Catalytic Gas Oil	42.4	.....	.....	.....	.....	.....	.....	9.8	100	13.3	35.6

catalyst without removal of straight run products. The flow arrangement for this operation is the same as described for residues. Many variations in flow are possible but the above are the principal ones.

In general the yield of gasoline will be about 45 percent, based on charge to catalyst, from a single pass operation on any stock, whether gas oil or residue. The octane number of the gasoline produced from any charging stock heavier than gasoline is from 77 to 81 for 437 E.P. gasoline. Octanes on Research Method will run 7 to 10 points above these figures. The octane value does not change to any appreciable extent with boiling points and these values are obtained regardless of type of crude. Lead susceptibilities and blending values are high. The blending value of Houdry with straight run gasoline is usually 4 to 10 points higher than the actual octane. Unless otherwise noted all references to octane value are on the basis of ASTM. Motor method rating.

Catalytically produced gas oils can again be cracked by the catalytic operation and the yield, while lower than obtained on virgin gas oil, is higher pass by pass, than is usually obtained in a thermal unit. Catalytically produced gas oils make excellent charging stocks for thermal units. Tests indicate that yields by thermal cracking of gas oils produced by one pass catalytic conversion will be at least as high as those shown in the table below. Octane numbers on the gasoline produced will be somewhat higher than on gasolines produced by thermal cracking of similar virgin gas oils.

A.P.I. Gravity of Catalytic Gas Oil Degs.	Thermal Gasoline Yields %	% 8° A.P.I. Fuel
20	50	38
27	54	34
34	58	30

Table No. 1 shows yields and product characteristics obtained from different residuum and crude oil charging stocks when run one pass and producing residuum fuel.

An outstanding feature of these catalytic operations is their ability to produce aviation gasoline. It is believed by the authors that the manufacture of aviation gasoline by this process, 7,000,000 gal. in 1937-1938, represents the first commercial application of a synthetic process for aviation fuel production.

This does not refer to synthetic anti-knock components such as iso-octane and iso-propyl ether, as such materials are blending agents and do not in themselves constitute complete aviation fuel. Houdry aviation gasoline when sweetened, acid treated and redistilled gives a product meeting acid heat specification, gum and oxidation tests. Houdry catalytic treating is applicable for the same purpose. Finished Houdry aviation gasoline will be from 76 to 78 ASTM Octane clear grade, or approximately 87, 90, 92 Octane with 1.8, 3 or 4 ml. of tetraethyl lead per gallon respectively.

Figure 1

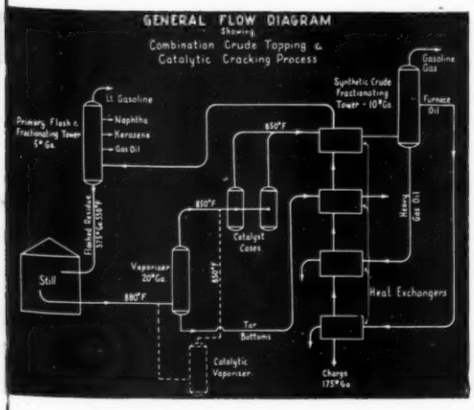


TABLE No. 2

Houdry Conversion of Gas Oil to Aviation Gasoline
Properties of Products

	Charge Stock to Houdry Unit	Stabilized Raw Aviation Gasoline Distillate	Heavy Naphtha Fraction	Raw Motor Gasoline	Recycle Gas Oil Bms.	Excess Butanes and Pentanes(1)*
Approximate Yields Based on Charge, By Vol.	100.0%	22%	20%	46%	53%	5% on Aviation 1% on Motor Gasoline
Gravity, °A.P.I.	29.0	63.0	36.0	53.0	27.0	
Distillation—A.S.T.M., °F. I.B.P.	395	105	300	95	418	
5%	433	130	316	125	444	
10	450	141	320	142	450	
20	471	154	325	176	460	
30	488	169	333	205	468	
40	504	185	339	230	480	
50	521	202	346	262	492	
60	538	215	355	292	505	
70	559	230	364	317	521	
80	585	244	373	344	542	
90	637	263	384	369	581	
E.P.	685	299	410	402	668	
Recovery, %	97.5	98.0	98.5	97.0	98.0	
Residue, %	1.5	1.0	1.0	2.0	2.0	
Loss, %	0.5	1.0	0.5	1.0	0.0	
Acidity of Residue	....	Neutral	....	Neutral	....	
Color, Saybolt		30+		28		
Reid Vapor Press., #/sq. in		7.0		10.0		
Doctor Test		Neg.		Neg.		
Acid Heat, °F		68		60		
Water Tolerance		Pass		....		
Freezing Point, °F.		Below —76		....		
Copper Dish Gum, Mgs./100 cc		1		6		
Copper Dish Corrosion		Pass		Pass		
Glass Dish Gum, Mgs./100 cc		1		1		
Sulphur, % by Wt.		0.02		0.03		
British Air Ministry Existent Gum		1		....		
British Air Ministry Potential Gum		1		....		
Octane Number, ASTM Motor Method		77.5	75.0	77.0		
Ditto +1 cc. Pb Et_4		84.0		82.5		
Ditto +2 cc. Pb Et_4		86.6		84.5		
Ditto +3 cc. Pb Et_4		88.5		86.0		
Ditto +4 cc. Pb Et_4		89.8		....		

(1)*—The yield of dry gas is 2.5% by wt. and catalyst deposit 1.5% by wt. In making aviation gasoline there is an excess of about 5% by volume of light ends consisting mainly of butanes and pentanes, but in making 10 lb. R.V.P. motor gasoline only about 1% excess is produced.

Properties of Treated and Catalytically Converted Aviation Gasolines

	Typical Untreated Catalytic Stock	Comm'l Acid Treated and Rerun	Mildly Acid Treated and Rerun	Houdry Vapor Phase Catalytic Treated	Houdry Liquid Phase Catalytic Treated
Yield Aviation Gasoline % of raw stock	100	84	94	91.5	86*2
Gravity, °A.P.I.	63.0	63.0	62.8	62.2	62.5
Distillation—A.S.T.M., °F. I.B.P.	105	106	108	110	104
5%	130	138	136	134	124
10	141	146	144	145	148
20	154	158	157	159	164
30	169	171	170	172	178
40	185	186	186	186	188
50	202	199	200	198	200
60	215	212	213	211	214
70	230	224	225	224	220
80	244	237	239	238	244
90	263	257	260	257	254
E.P.	299	310	320	289	290
Recovery, %	98.0	98.0	98.0	98.0	97.0
Residue, %	1.0	1.2	1.0	1.0	1.0
Loss, %	1.0	0.8	1.0	1.0	2.0
Acidity of Residue	Neutral	Neutral	Neutral	Neutral	Neutral
Color, Saybolt	30+	30+	28	30+	30
Reid Vapor Press., #/sq. in	7.0	5.9	5.5	6.6	6.2
Doctor Test	Neg.	Neg.	Neg.	Neg.	Neg.
Acid Heat, °F	68	14	48	21	9
Water Tolerance	Pass	Pass	Pass	Pass	Pass
Freezing Point, °F.	Below —76	Below —76	Below —76	Below —76	Below —76
Copper Dish Gum, Mgs./100 cc	1	1	1	Below 1	1
Copper Dish Corrosion	Pass	Pass	Pass	Pass	Pass
Glass Dish Gum, Mgs./100 cc	1	Below 1	Below 1	Below 1	Nil
Sulphur, % by Wt.	0.02	0.01	0.01	0.02	0.01
Brit. Air Ministry Exist. Gum	1	1	1	1	....
Brit. Air Ministry Potent. Gum	1	1	1	1	....
*1 U. S. Navy Accelerated Gum:					
Old Test, 4 Hrs., Mgs./100 cc	....	2	1	2	1
New Test, 5 Hrs., Mgs./100 cc	....	5	1	—*3	....
Octane No., ASTM Motor Method	77.5	78.0	77.7	79.2	77.4
Ditto +1.0 cc. Pb Et_4/Gal.	84.0	85.0	84.6	86.0	84.7
Ditto +2.0 cc. Pb Et_4/Gal.	86.6	88.2	87.8	88.6	87.2
Ditto +3.0 cc. Pb Et_4/Gal.	88.5	90.7	90.0	90.6	88.8

*1—Old Navy test was for 4 hrs. @ 212°F. under 100 lbs. initial oxygen pressure before heating; New test is similar but for 5 hrs. and in the presence of an iron strip.

*2—There is produced in addition to the 86% of aviation gasoline 5% of 77.9 octane 414°F. E.P. naphtha and 8% of 29.8° API gravity gas oil.

*3—This sample showed only 2 mgs./100 cc. gum after 8 hrs. aging in bomb without iron strip.

TABLE No. 3

Yield and Product Characteristics Running Gas Oils—One Pass

	Mid-Continent Gas Oil	West Texas New Mexico Gas Oil	East Texas Gas Oil	Coastal Gas Oil
Sulphur content of chg. to plt	0.22	.81	.16	0.04
Chg. to Catalyst, A.P.I. Gr.	37.8	30.4	34.5	30.0
" " " , I.B.P.	416	440	420	406
" " " , 50%	536	554	574	494
" " " E.P.	656	683	750	602
Dry Gas, % wt. chg. to cat.	4.3	5.2	6.1	4.9
Catalyst Deposit, % wt. chg. to cat.	3.3	4.0	3.2	1.0
Gasoline, % vol. chg. to cat.	44.7	41.0	44.4	50.3
" , A.P.I. Gr.	64.4	60.8	62.7	56.8
" 50%	233	230	242	260
" 90%	346	354	362	382
" E.P.	398	404	402	410
" R.V.P.	13.0#	10.0#	11.0#	11.0#
" Sulphur Content—%	0.02	0.07	0.02	0.01
" Copper dish gum	3	9	4	4
" A.S.T.M. m.m. Octane	79.2	79.3	77.0	80.8
Catalytic Gas Oil, % vol. chg. to cat.	53.0	55.3	51.9	49.9
" " " A.P.I. Gr.	35.2	27.4	31.0	26.6
" " " I.B.P.	409	419	468	414
" " " 50%	510	516	550	480
" " " Pour point °F.	+5	—(—60)	+15	—(—60)
" " " S.U. Vis. at 100°F.	36	37	36	34
" " " Sulphur content—%	0.07	0.80	.10	0.10
" " " Aniline Point °F.	148	116	142	74
Liquid Recovery % vol. chg. to catalyst	97.7	96.3	96.3	100.2
Percent of 32° A.P.I. Gr. Furnace Oil in Catalytic Gas Oil	100	40.2	90	.....

TABLE No. 4

Yield and Characteristics Running Crudes—No Residuum

	Mid-Continent 17.5% Crude Btms.	Lagunillas 100%	West Texas New Mexico 35% Btms.
Chg. to Plant % crude	17.5	100%	35
Sulphur content of chg. to plt	0.77	2.14	2.20
Chg. to catalyst, % vol. crude	17.5	100.0	35.0
" " " A.P.I. Gr.	17.8	17.3	17.1
" " " I.B.P.	550	160	576
" " " 50%	760+	760+	731+
" " " E.P.	760+	760+	760+
Dry Gas, % wt. chg. to cat.	5.0	4.3	3.9
Catalyst Deposit, % wt. chg. to cat.	13.8	11.9	7.8
Gasoline, % vol. chg. to cat.	47.7	44.9	39.4
" A.P.I. Gr.	60.3	58.2	59.2
" 50%	243	266	267
" 90%	347	388	355
" E.P.	399	414	388
" R.V.P.	12.0#	11.0#	10.0#
" Sulphur Content—%	0.11	0.20	0.21
" Copper dish gum	30	65	76
" A.S.T.M. m.m. Octane	79.1	78.6	79.8
Catalytic Gas Oil, % vol. chg. to cat.	46.1	50.0	58.8
" " " A.P.I. Gr.	24.4	21.5	20.2
" " " I.B.P.	423	432	424
" " " 50%	576	574	654
" " " Pour point °F.	+40	—35	+45
" " " S.U. Vis. at 100°F.	42	43	56
" " " Sulphur content—%	0.40	1.41	1.47
" " " Aniline Point °F.	118	104	135
Liquid Recovery % vol. chg. to catalyst	93.8	94.9	98.2

When used for blending with iso-pentane, iso-octane and similar anti-knock agents, 100 Octane grade fuel after lead addition is produced. For example, a typical 100 Octane number Army method (96 Octane motor method) blend, actually marketed, consists of about 25 percent iso-octane, 75 percent Houdry aviation gasoline and 2.75 cc. of lead. This blend indicates that only ½ as much iso-octane is required as with natural aviation gasoline from selected crude.

Table No. 2 shows typical properties of Houdry aviation gasolines.

Table No. 3 shows yields and typical properties of products from Houdry conversion of gas oils.

The so-called "no-residuum" operation flow is shown by dotted lines in Figure I, the catalytic vaporizer replacing the tar separator vaporizer. In this operation the residual carbon is deposited on the catalyst which is regenerated by burning off the deposited carbon with air. Most of the heat value of this carbon is recovered, part of this heat being used to supply heat of reaction in the conversion operation and part being recovered as steam and power. The carbon deposit in the catalytic vaporizer will vary from 1.5 percent by weight obtained when charging 34.7 percent reduced Lafitte Crude, to 7 percent by weight when charging a 17.3 deg. A.P.I. Venezuela (Lagunillas) crude. The vapors leaving the catalytic vaporizer and entering the catalytic cracking units represent 99.4 percent by liquid volume of the charge to the vaporizer on the Lafitte charge and 94.6 percent on the Lagunillas. The combined catalytic operation of vaporization and cracking is noteworthy on account of the high liquid recovery, low coke make, substantial absence of low grade naphtha on the vaporizing side, and practically complete volumetric conversion of the heavy components of the charge to cracking catalyst into gasoline and gas oils. Table No. 4 shows yields and general tests from runs by this method.

Table No. 5 shows results obtained by recycling.

Attention is called to the important appreciation of final products obtainable by the Houdry Process Corporation process as compared to thermal processes. The outstanding advantages of the H.P.C. process are:

(1) High yield of high octane gasoline in one pass.

(2) Production of light gravity, low boiling point gas oil as cycle stock or as furnace oil in place of fuel oil.

(3) Low gas yields.

(4) High liquid recovery.

(5) Flexibility in meeting seasonal variation in demand of furnace oil, fuel oil and gasoline.

(6) Availability of the process as a source of aviation gasolines without change in equipment.

In general, the authors desire to emphasize that

(a) Heavy fuel oils are eliminated, the Houdry finished products consisting entirely of gas, gasoline, and gas oils.

(b) Type of crude has substantially no effect on yield or octane number of gasoline produced by the catalytic cracking.

(c) On all crudes so far tested, sulphur content of gasoline produced by catalytic cracking and treating is below .1 percent.

TREATING

Houdry Process Corporation has available two treating operations. One is a vapor phase catalytic process for treating catalytic or thermal gasoline; the other is a liquid phase catalytic process for treating catalytic aviation gasoline.

The vapor phase operation produces, with no loss of octane, a gasoline having unusually low gum tests, sweet to doctor, high stability and low sulphur, excellent color and odor. Catalytic untreated gasoline has low gum content, induction periods of 10 hours or more, low sulphur and, in most instances, colors sufficiently good to enable dyeing. The untreated gasoline will not pass the doctor or corrosion test but after a caustic soda wash will pass the corrosion test.

TABLE No. 5

Yield and Product Characteristics Obtained by Recycling

	Virgin Stock	2nd Pass	3rd Pass	Residual Gas Oil	Virgin Stock	2nd Pass	3rd Pass	Residual Gas Oil	Virgin Stock	2nd Pass	Residual Gas Oil
Charge % of Virgin Stock	100%	53.0	35.3	25.2	100%	46.1	33.8	26.0	100	53.9	32.7
A.P.I. Gr.	37.8	35.2	33.7	32.4	17.8	24.4	22.8	21.2	27.5	29.4	22.3
I.B.P.	416	409	432	420	550	423	422	426	440	448	440
50%	536	510	506	498	760+	576	555	532	680	576	585
90%	586	566	560	554	760+	745	712	676	760+	710	702
E.P.	656	656	660	683	760+	760+	760+	760+	760+	760+	760+
Aniline Point	179	148	134	125	....	118	100	90	....	148	124
Cumulative Yield of Gasoline % Vol.	44.7	59.5	67.2	....	47.7	54.0	62.9	....	45.5	62.3	....

TABLE No. 6

Yields and Inspection of Gasolines Treated by Catalytic Process

COMPONENTS OF RAW GASOLINE	EAST TEXAS: Houdry Cracked Gaso. from 62% Btms. of Crude	EAST TEXAS: Houdry Crkd. Gaso. from 62% Btms. of Crude	EAST TEXAS: Str. Run Gasoline	EAST TEXAS: Thermally Refmd. Str. Run Naptha	EAST TEXAS: Houdry Crkd. Gaso. from 62% Btms. of Crude	EAST TEXAS: Straight Run Gasoline	WEST TEXAS: Houdry Crkd. Gaso. from 68.5% Btms. of Crude	WEST TEXAS: Houdry Crkd. Gaso. from 68.5% Btms. of Crude	WEST TEXAS: Str. Run Gasoline	WEST TEXAS: Thermally Refmd. Str. Run Naptha	WEST TEXAS: Straight Run Gasoline
% of Components	100.0	44.0	31.7	24.3	41.0	59.0	100.0	51.0	26.5	22.5	100
Treating Yield											
Gas. % Wt. Charge	0.4		0.8		0.5		0.30		0.3		0.5
Cat. Depos. % Wt. Chg.	0.2		0.3		0.3		0.45		0.3		0.5
Polymers % Vol. Chg.	0.2		0.1		0.6		0.25		0.1		0.3
Treated Gaso. Vol. Chg.	99.2		98.8		98.6		99.0		99.3		98.7
INSPECTION OF GASO.											
A.S.T.M. Distillation											
Gr. A.P.I.	60.6		59.1		58.4		56.5		58.5		58.2
I.B.P.	94		90		106		84		94		95
50%	232		238		256		256		238		268
EP	382		417		402		422		371		391
Rec.	97%		97%		97%		96%		97%		97
Res.	1.2		1.0		1.2		0.4		1.4		0.8
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Si Dish Gum	0	0	2	1	0	1	1	1	1	1	6	0
Cu Dish Gum	3	3	15	4	5	5	13	5	11	6	8	1
Sulphur	0.02	0.01	0.04	0.02	0.04	0.02	0.15	0.08	0.11	0.06	0.19	0.06
Doctor	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet
Cu. Strip	Tarn	OK	Tarn	OK	Tarn	OK	Tarn	OK	Tarn	OK	Tarn	OK
Oxy. Bomb Ind. Per.-hrs.		10+		10+		10+		10+		10+		10+
Lead Susc.												
C.F.R. + Occ.Pb/Gal	78.0	77.8	71.1	71.4	66.5	66.9	76.6	77.0	74.2	74.0	63.3	63.8
" ½ " "	80.9	80.8	75.0	76.2	71.0	70.7	79.0	79.6	77.8	77.9	65.6	68.8
" 1 " "	82.7	82.2	78.2	79.1	74.4	74.0	80.2	81.1	78.8	79.0	68.3	71.2
" 2 " "	84.1	84.3	80.8	82.0	78.9	78.4	81.4	82.3	81.0	81.2	—	—
" 3 " "	85.1	85.3	82.3	82.8	80.9	80.3	82.3	83.4	82.0	82.4	74.3	79.2
Color	21	30	18	30	25	30	14	28	20	30	24	30

The untreated catalytic gasoline of 424 E.P. from 68.5 percent reduced West Texas crude has a sulphur content of only 0.14 percent whereas 300 deg. E.P. untreated straight run gasoline from the same crude has a sulphur content of 0.18 percent. The vapor phase treatment completely removes mercaptans and hydrogen sulphide and at least 30 percent of the original total sulphur. The vapor phase operation may be effectively used on thermally cracked gasolines. Operating costs vary from 2.5 to 4.5 cents per barrel charged and the yield is normally in excess of 99 percent from catalytic gasoline. Two plants with charging capacity each of 22,000 bbl. per day are being erected. A 1,500 bbl. per day unit has been successfully operated for one year on catalytic gasolines from various charging stocks, including heavy distillates of Iraq crude.

The process consists of passing the vaporized gasoline at a temperature of about 600 deg. F. and pressures from 15 lb. to 100 lb. gauge over molded solid catalyst of acid treated clays containing oxides of the heavy metals, manganese and nickel. The catalyst is regenerated in place as required, usual operating periods being from four to six hours; two cases are used, thus giving a continuous operation. The quality of products obtained by catalytic vapor phase treatment is shown in Table No. 6.

Liquid phase treatment of aviation gasoline by catalysts results in a product having acid heat numbers of approximately 10, bromide numbers of three or lower and other characteristics such as sulphur, gum, stal ility, etc., meeting all requirements. Some results of this operation are shown in Table No. 2. Exceptionally high blending characteristics are obtained with iso-octane and lead as previously mentioned.

TABLE NO. 7

Typical H.P.C. Polymer Yields and Products

Composition of Chg. Stock, Mol. % Iso Butylenes	N-Butylene	Butanes	C_5+	% Polymerization Mol. % of Total Butylenes (No Recycling)
5.4	16.6	78.0	0.0	55
9.2	18.8	71.0	1.0	57
15.0	25.2	59.8	0.0	62
18.9	24.6	56.5	0.0	72

Typical Operating Yields

	Chg. Stk. % Gas Vol. (Mol. %)	Weight Balance % Wt. Chg.	% Wt. Prod.	Liquid Balance % Vol. of Chg. Chg. Liq.	% Vol. of Chg. Prod.
Butylenes	28.0	27.7	11.8	26.9	11.5
Butanes	71.0	70.8	70.8	71.8	71.8
Pentanes*	1.0	1.5	17.4	1.3	13.3*
Catalyst Deposit	.....	.....	0.02	.....	.....
	100.	100.	100.	100.	96.6

* Yield of polymers (C_5 and heavier) on unsaturates transformed is 99.9% by wt.

Products

	Polymer Gasoline	Aviation Cut	Gas Oil Cut
% of Total Polymers	88.5%	45.5%	11.5%
Gravity °A. P. I	56.4	61.8	38.5
Initial	216	210	440
5%	234	220	460
10	244	222	467
50	296	227	500
90	362	233	622
95	376	238	632
E. P.	402	263	656
Recovery	97%	98	98.0
Color	30	30	
Dr. Test	Sweet	Sweet	
Cu Strip	OK	OK	
Sulfur	0.01	0.005	
Si dish gum	0.0 mg.	0.0 mg.	
Cu dish gum	1.0 mg.	1.0 mg.	
R. V. P./100	1#		
C. F. R. Octane	84.7	84.7	

Blending Value of Polymer Gasoline

% Polymer Gasoline	% Str. Run Gasoline CFR 60.2	% A-5 Reference Fuel CFR 40.3	ASTM-CFR Octane	Blend Value
10	90		64.7	105
20	80		69.6	107
40	60		78.6	106
10		90	49.8	136
20		80	58.8	133
40		60	72.2	120

DESULPHURIZATION

Catalytic desulphurization is available for the substantially complete removal of sulphur from refinery gases. The process requires a higher capital investment than some others when sulphur content is below 1,500 grains per 100 cu. ft. but has comparable operating costs. For higher sulphur contents or where complete removal is required the authors believe it offers more advantages than any competing process, since the costs and the operation are practically independent of the sulphur content of the gas. In general the operation consists of heating the sulphur bearing gas to temperatures of about 750 deg. F. at any convenient pressure, passing the heated gas over supported nickel oxide for a period of 30 minutes or more, interrupting the flow and regenerating under such conditions as to minimize the formation of nickel sulphate.

When coke oven gas containing 400 grains of H_2S and 45 of CS_2 was processed, 96.5 percent of the CS_2 was removed and simultaneously the H_2S was reduced to less than one grain per 100 cu. ft. No commer-

(Continued on page 132)

TABLE NO. 8

Viscosity Breaking Heavy Crude Residuals

	(1) West Texas New Mexico Crude	(2) 55% Grade B Coastal and 45% E. Texas
Residue Charge		
% of crude	8.5	8.1
Gravity °A. P. I	8.5	12.6
Viscosity S. U. @ 210°F	....	734
Sediment	0.3	0.01
Gas Oil *1		
% of charge	3%	5%
Gravity °A. P. I	20.2	25.7
Viscosity S. U. @ 100°F	58	68
Fuel Oil Product		
Gravity °A. P. I	11.6	14.5
Viscosity S. F. @ 122°F	145	159
Pour	+30	+25
PM Flash	150	154
Sediment	0.4	0.08
Volume % on residue charge	98.5	102
Naphtha Volume % on residue chge.	1.0	2.1
Gas Weight % on residue chge.	3.5	1.5
Catalyst Dep. Wt. % on residue chge.	1.8	0.4

*1 Gas Oil used for washing in process and appearing in final product.

CORROSION-Resistant Steels in Cracking Plants

By E. S. Dixon, Metallurgist, The Texas Company

MODERN petroleum refining is relatively new. The early equipment was manufactured from the commonly known metals of the period—cast iron, steel, wrought iron and brass. With the advent of higher pressures and temperatures, and the processing of corrosive oils, metallurgy took a prominent place in the refining industry.

This paper deals with some of the locations where relatively high alloyed steels have been found indispensable. Carbon steel is usually preferred even today for the construction of vessels such as soaking drums and towers and other equipment which can be protected against corrosion by suitable liners.

Approximately 15 years ago, a study of suitable metals for pressure service was made by The Texas Company and others. Chromium alloys and aluminum showed remarkable resistance to corrosion in cracking equipment, particularly at high temperatures; however, the physical properties of aluminum limits its use under temperature.

Figure 1 is the well-known curve showing average relative corrosion rates of varying chromium content steels. This curve was made from specimens suspended in the vapor space of a soaking drum. It is not the purpose of this paper to review the literature with respect to properties of alloys which are identified by this curve.

Much information has been published by alloy manufacturers and fabricators of cracking plant equipment. This paper deals with the use of the available information by The Texas Company and does not pretend to speak for the industry as a whole.

From the curve in Figure 1 was selected the 4-6 percent chromium, and it has been successfully used as furnace tubes, bubble towers angle iron tray supports, outside lines, cast valves and return bends. The increased service life due to 4-6 percent chromium varies from three times the life of carbon steel to 20 times the life of carbon steel (depending upon severity of corrosion). The greater the corrosion rate due to sulphide corrosion, the more valuable is this alloy.

Temperature plays an important part in its usefulness; from 600 deg. F. through the maximum temperatures usually encountered it finds a real use. For lower temperatures its value is not so pronounced.

Protection of the tubes by coke deposit decreases in some instances the necessity for protection from corrosion obtainable by the use of chrome tubes.

The first 4-6 percent chrome tubes were manufactured without molybdenum which later has been added to prevent cold brittleness. This alloy (without molybdenum) has made a creditable performance. In one plant, 2,000 heater tubes, 30 ft. long, have been in service since 1930, with an additional expected life of four years. Many tubes have been replaced in the past eight years but not from corrosion. Scaling, bulging and warping—all of which are the results of over heating, have caused the removal of tubes.

This alloy takes punishment; only two fires are on record and these were not serious. Furthermore, they were from causes other than the properties of the alloy. Many tubes have swelled for a considerable length of the tube with no sudden rupture.

This alloy (without molybdenum) is subject to cold brittleness, and approximately 30 tubes, in their early use, split during down periods as a result of knocking. There have been no fires resulting from brittle tubes because the brittleness disappears as the tubes are heated. The obvious thing to do is to warm the tubes when knocking with coke cleaning tools, in which event failures from cold splits are rare. Figure 2 shows a brittle failure.

Referring to Figure 1, the range of 4-6 percent chrome content was chosen for refinery service as a matter of judgement; alloys of higher chrome increase rapidly in price while alloys of lower content, in some tests, did not exhibit much superiority in corrosion resistance to carbon steel, however as the use of the 4-6 percent chrome became more prevalent, and as greater knowledge of its properties and performance became known, many modifications were made by manufacturers. The chromium was lowered in some cases and raised in others. Higher silicon, aluminum, tungsten, molybdenum, titanium and columbium were added by various vendors, each addition being advocated for a particular purpose such as stability, scale resistance, elimination of air hardening and many other reasons. The alloys advocated are so numerous that detailed and careful study is required to make proper selection of the alloy best adapted to a particular service.

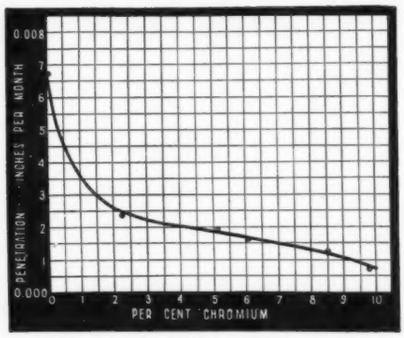


Figure 1.

Figure 2—Split resulting from cold brittleness in 4-6 chrome tube.

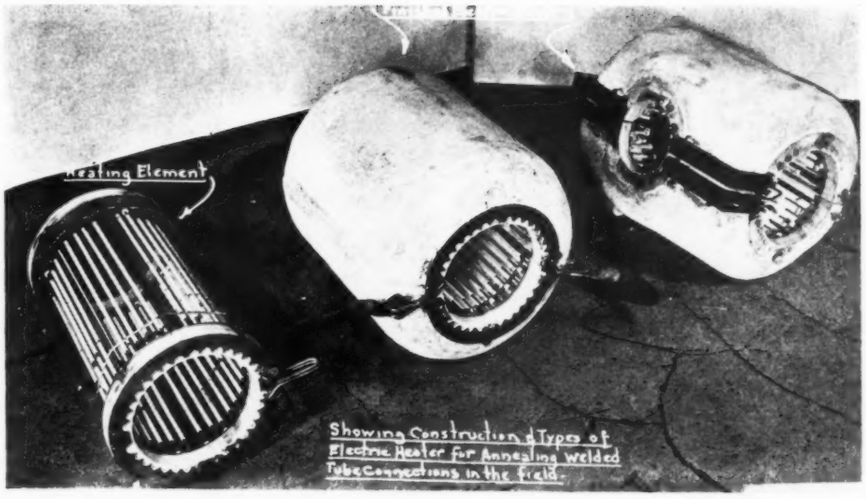


Figure 3.

Figure 4—Right, showing improved ductility by annealing 4-6 chromium field welds.

Table I gives the grades of some of the common alloys now on the market. There are others not included, no attempt is being made by the writer to list every alloy available.

TABLE I

Carbon			
Carbon-Molybdenum			
½ Percent Chromium		½ Percent Molybdenum	
2 Percent	"	½ Percent	" 1 Percent Silicon
4-6	"	½	" ½ Percent Silicon
9 Percent	"	1.15 Percent	"
18 Percent	"	8 Percent Nickel	

The designing engineer must select one grade of steel for his furnace, or he may select several different steels provided he has information as to where corrosion is high or where scaling and bulging are prevalent. The proper selection is based on knowledge of the corrosive nature of the oil as well as furnace conditions, and whether or not protective coke deposition occurs in the particular section of furnace being considered. If there is a lack of information regarding these items, the designer sometimes builds with carbon steel knowing that he must rebuild within a year or two. He will, at that time, have some knowledge as to the locations where alloys can be justified.

From Table I, The Texas Company usually selects carbon steel, two percent chrome-molybdenum, 4-6 percent chrome-molybdenum and nine percent chrome-moly. In some low temperature, highly corrosive pipe stills 18-8 is in service. The 4-6 percent chromium has been satisfactory over a period of years in many furnaces; however, where corrosion is low, its price forbids its use and two percent chrome-molybdenum is now receiving consideration. This alloy tube has much better high temperature properties than carbon steel, corrodes much less than carbon steel and seems to have merit for furnace tube when running relatively non-corrosive oil.

Although better than carbon steel, two percent chrome is not at all satisfactory under highly corrosive conditions and at least one refinery must use nine percent chrome, which is giving satisfactory results.

In like manner, carbon steel is used for outside pressure lines where corrosion is low, 4-6 percent chrome-molybdenum for more severe corrosion, and 18-8 is installed where replacements due to corrosion is severe.

The selection of the alloys for minimum overall cost, taking into account the life of the installation as a whole, is obviously a very complicated problem, the solution of which depends on knowledge of corrosion in various locations. In the case of new installations recourse must be had to corrosion rates on similar equipment charging similar stock, which, of course, is very approximate. For instance, in some cases it may be desirable to install all carbon steel furnace tubes and when replacements are necessary corrosion rates at various locations will have been established with sufficient exactness to permit more satisfactory selection of the alloy giving minimum cost.

The Texas Company has a wider experience with 4-6 percent chrome than other alloys and the following represents their findings:

"The use of 4-6 percent chrome in place of carbon steel is a matter of dollars and cents, balancing the higher original cost of the alloy against the materially longer life it will exhibit in the face of corrosive attack. Corrosion is not the only factor terminating the useful life of a part, however, and a predicted life based on all the factors (bulging and splitting, as well, for heater tubes, and obsolescence for all parts) must be established for construction based on each material, as well as the first cost, before reaching a decision.

"Experience is that the 4-6 percent chrome alloy exhibits a valuable resistance only against the sulphide type of corrosion in substantially non-aqueous conditions. That is, only as pressure stilling parts, and not, for example, as naphtha run down lines, tank roofs, etc.

"With regard to pressure still corrosion, however, 4-6 percent chrome shows more and more favorably as the corrosion becomes more severe. In service as at plants where the corrosion is mild test data indicate that for many parts 4-6 percent chrome would not have a life much greater than carbon steel, which, in any event, endures for as long a period as is economical. But the plants which handle sour oils find that a 4-6 percent chrome tube will give four to eight times the life of a steel tube.

"We are giving below a table of relative corrosion rates as determined by test samples in various locations. The ratios of corrosion rates are not to be taken too literally, because they are not based on service of actual fittings."

TABLE II

Corrosion Rates, Carbon Steel and 4-6% Chromium Steel in Pressure Stilling Service-(A.P.I. Test Procedure) Tested in Various Refineries

Carbon Steel	4-6 Percent Chrome	Location	
0.03"/Yr.	0.04"/Yr.	Furnace,	750 deg.
0.09"/Yr.	0.02"/Yr.	Furnace,	980 deg.
0.08"/Yr.	0.005"/Yr.	Soaking Drum,	770 deg.
0.11"/Yr.	0.03"/Yr.	Soaking Drum,	815 deg.
0.21"/Yr.	0.03"/Yr.	Furnace,	900 deg.
0.40"/Yr.	0.14"/Yr.	Soaking Drum,	760 deg.
1.05"/Yr.	0.04"/Yr.	Furnace,	790 deg.
1.74"/Yr.	0.04"/Yr.	Furnace,	770 deg.

Until recently, the use of chromium alloy steels in equipment of the oil industry operating at high temperature and pressures was limited to cracking coils and other locations where fabrication in the field did not necessitate welding. In many locations where corrosive high sulphur bearing oil stocks are processed in pressure equipment, it is desirable to use chromium alloy steels instead of plain carbon steel which has very poor resistance to corrosion at high temperatures. The fact that nearly all outside pressure lines are welded has discouraged

Figure 5—Field annealed welds.

the use of chromium steel tubing in such locations, since high welding heats will impart detrimental properties of brittleness to alloys. This property of chromium alloy steel, imparted to it during the cooling of a weld, is most commonly called "air hardening."

To restore the desirable properties such as ductility, and good resistance to shock, of an air hardened chromium alloy steel specimen, it is only necessary to heat the material above the critical range (1575 deg. F) and allow it to cool very slowly in order to restore the properties of ductility, softness, and impact to a metal that has once been hard and brittle.

Until recently, the heat treatment necessary for relieving the hard properties of a welded connection could only be satisfactorily accomplished in certain types of stationary shop furnaces which are in most cases not accessible to welded connections made in the field.

Through a recent development the annealing of field welds can be accomplished by using a resistance type of electric furnace designed to operate on the electric power supplied from a 300 ampere welding machine. Now it is possible as well as practical and economical to anneal any field welded connection wherever it is possible to electric weld.

Figure 6—Cracked hot oil pumps.

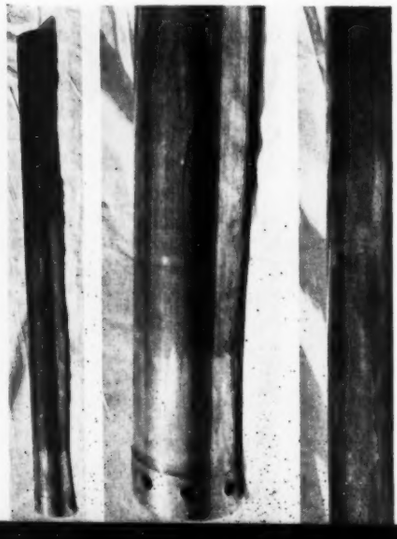


Figure 3 illustrates the types of furnaces used. In general, this furnace consists of two half cylindrical sections which can be enclosed around a chromium alloy steel welded tube connection. The heating elements consist of two chromel wire hair-pin type coils which are in parallel and are so arranged that the tube section containing the weld will be heated uniformly. The heating element sections and the tube for 12 in. from each end of the furnace are covered with high temperature insulation of 1½ in. thickness. The insulation sections around the tube at the ends of the furnace assist the operator in obtaining better control of the temperatures during the heating and cooling operations. The temperature during the annealing operations is determined by means of a potentiometer connected to a thermocouple which is attached at a point on the outside surface of the weld.

An example of the field annealing of a chrome alloy steel welded five inch OD tube connection is described as follows:

After the furnace is properly installed around the welded connection, it is connected by means of ordinary welding cables to a 300 ampere welding generator. The welding generator is adjusted to deliver approximately 150 amperes to the furnace. At this amperage (heat) it will require approximately 70 minutes to heat the weld connection to 1600 deg. F. The weld connection is allowed to "soak" at this temperature for 30 minutes by cutting the amperage down to 125. After the "soaking" period the temperature of the furnace is dropped at the rate of three to five degrees F. per minute until 1200 deg. F. is reached. This can be easily accomplished by gradually reducing the amperage delivered by the welding machine. At 1200 deg. F. the current is cut off and 20 minutes later the furnace is removed from the welded tube connection. The weld is then allowed to cool in the air to atmospheric temperature.

A hard 4-6 percent chromium alloy steel welded connection having a Brinell hardness number of 375, when given the above heat treatment will have a Brinell hardness number of 143 which is an indication that the once hard brittle weld connection is now very tough and ductile. Other physical properties were as follows:

Tensile Strength	72,300 p.s.i.
Elongation over 8 in.	28.5 percent
180 deg. Bend Test	O.K.

Figure 4 shows two welded bars which were taken from a field welded 1⅝ in. O.D. tube connection. The extent and character of the brittleness of a weld connection before and after annealing may be readily seen. The dark area in the parent plate adjacent to the weld reveals the extent to which this plate was affected by the heat from the electric welding operation. The

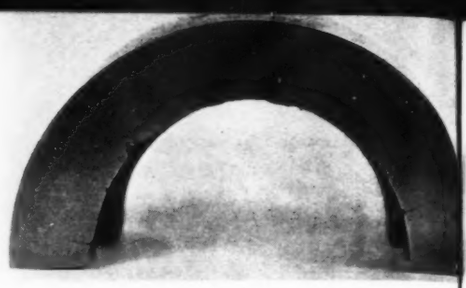
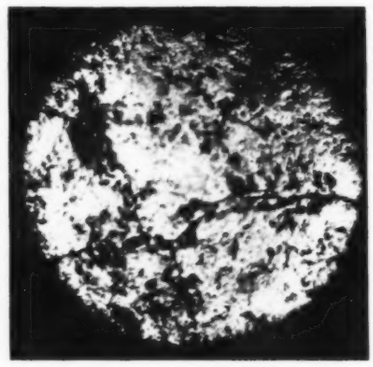
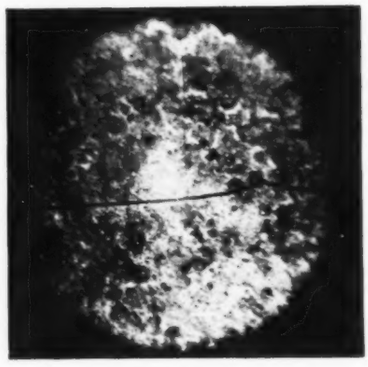
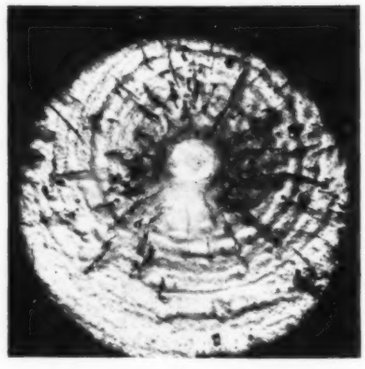


Figure 7—Cracks in hot oil pump plunger revealed by Boroscope.

Figures 8, 9 and 10—Defects in plungers as discovered by Boroscope, which has end view and side viewing heads.







method described is the subject of a United Srates patent application, which will mature into a patent in the near future.

The chromium alloy steels should be welded with an extruded coated electrode whose chemical composition is very similar to the parent plate. In no case should the carbon content of the electrode be greater than 0.15 percent. Too great an electrode carbon content will cause trouble during the welding operation.

An average and intelligent first class welder can learn very readily to make chromium alloy steel welds of good character in a very short time after he has become acquainted with the electrode. The welder should familiarize himself with the working characteristics of the electrode by making trial welds and breaking them to observe the character of the deposited metal.

Newly deposited weld metal of chromium alloy steel is very brittle at atmospheric temperature, but at a temperature of 200 deg. F. or greater it is tough and ductile and will withstand any sudden stress without cracking. It is good practice to anneal the finished weld immediately after the welding operation is completed.

Figure 5 shows the type of chromium alloy steel welds that have been annealed in the field.

Previously the plungers of our hot oil pumps were usually stainless steel of a cutlery analysis, and had a tendency to develop cracks, with ultimate failure, which is a result of exposure to oil temperatures as high as 800 deg. on the outside with water cooling inside. Figure 6 shows a crack which occurred in a longitudinal direction; the crack was approximately four feet long and up to $\frac{1}{16}$ in. in width, and proceeded in a radial direction. Cracks may also occur in a transverse direction.

Approximately one year ago we purchased a Zeiss bore inspection telescope (Boroscope) for the purpose of inspecting the bore of our hot oil pumps.

The first plunger inspected was a spare, but used, plunger. Cracks were very clearly seen in the bottom and bore of this plunger. While none of them were very large they were present in the plunger. Therefore, in order to learn more about this plunger and the cracks in it, it was cut up. Figure 7 shows a section of the bottom of the bore of this plunger. It is to be noted in this photograph that there are both circumferential and longitudinal cracks present in the plunger and that the entire bore was very rough due to corrosion. The circumferential cracks extended entirely around the bore and were up to $\frac{1}{4}$ in. in depth. Longitudinal cracks were from $\frac{1}{4}$ in. to three inches in length and as much as $\frac{3}{8}$ in. deep.

Figure 9 shows a crack which had ruptured the wall.

Figures 8 and 10 show defects discovered only with the Boroscope.

By means of this instrument many dangerous plungers have been taken out of service and confidence is felt that those left in are safe to operate.

Study is made by cutting a cross section across defective plungers; many minute cracks exist, as shown in Figure 11. Some cracks have just started, while others extend nearly through the plunger wall.

In order to reclaim the liquid ends of hot oil pumps, the following novel method is being tried:

The ports and passages of the cylinders are remachined oversize, then filled with molten metal of 4-6 percent chrome composition and remachined to the proper dimensions. By this means a corrosion resisting cast liner is obtained in the original forged cylinder.

To date there have been two blocks filled with molten metal.

1st Block

All the ports and passages in the first block were machined oversized. Two inch carbon steel bars were put in longitudinal suction and discharge ports, to serve as cores. The block was put in a cast iron box and sand was packed around it. The necessary risers were also made of sand. The block was then warmed to take the moisture out.

Molten metal of 4-6 percent chromium type analysis was poured into the cylinder through the discharge port opening. The analysis of the liner metal obtained is shown below:

	Percent
Carbon	.16
Manganese	.45
Silicon	.31
Chromium	4.95
Molybdenum	.50

After the risers were removed the block was annealed.

2nd Block

In handling the second block after remachining all ports, the longitudinal suction port was cored full length with four inch shafting, the discharge port with three inch and the plunger cylinder with six inch shafting. Twelve inch risers were made of steel tubing, which was tack welded to the pump block. All the openings were plugged with tack welded steel plates.

When delivered to the foundry this block was heated to 1400 deg. F. and was removed from the furnace just before the melt of 4-6 percent chromium steel in the electric furnace was fully made. The molten metal was poured into the block 15 minutes after the latter was removed from the heating furnace. In this block the metal was poured into the suction chamber through the suction valve port. The analysis of the liner metal obtained is shown below:

Figure 11—Defects revealed by Boroscope.

	Percent
Carbon	.22
Manganese	.95
Chromium	5.48
Molybdenum	.50

As with the first block, after the risers were removed the block was annealed at the foundry.

Machining of the cylinders revealed several defects, flaws and cracks in the metal.

In the first block the chromium liner shrunk away in places. This can be seen in Figure 12.

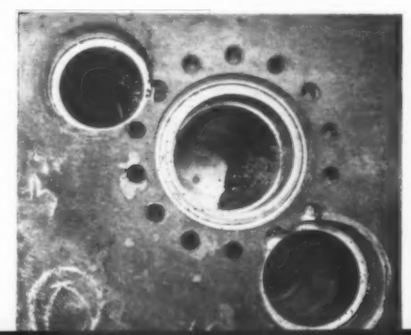
The above demonstrates that forge steel liquid ends of hot oil pumps can be repaired in the manner described. The pump cylinder was filled with molten metal, remachined, all defects repaired, thus the manufacture of corrosion resistant liner was realized. The cylinder block successfully withstood the inspection test pressure and has been in service five months.

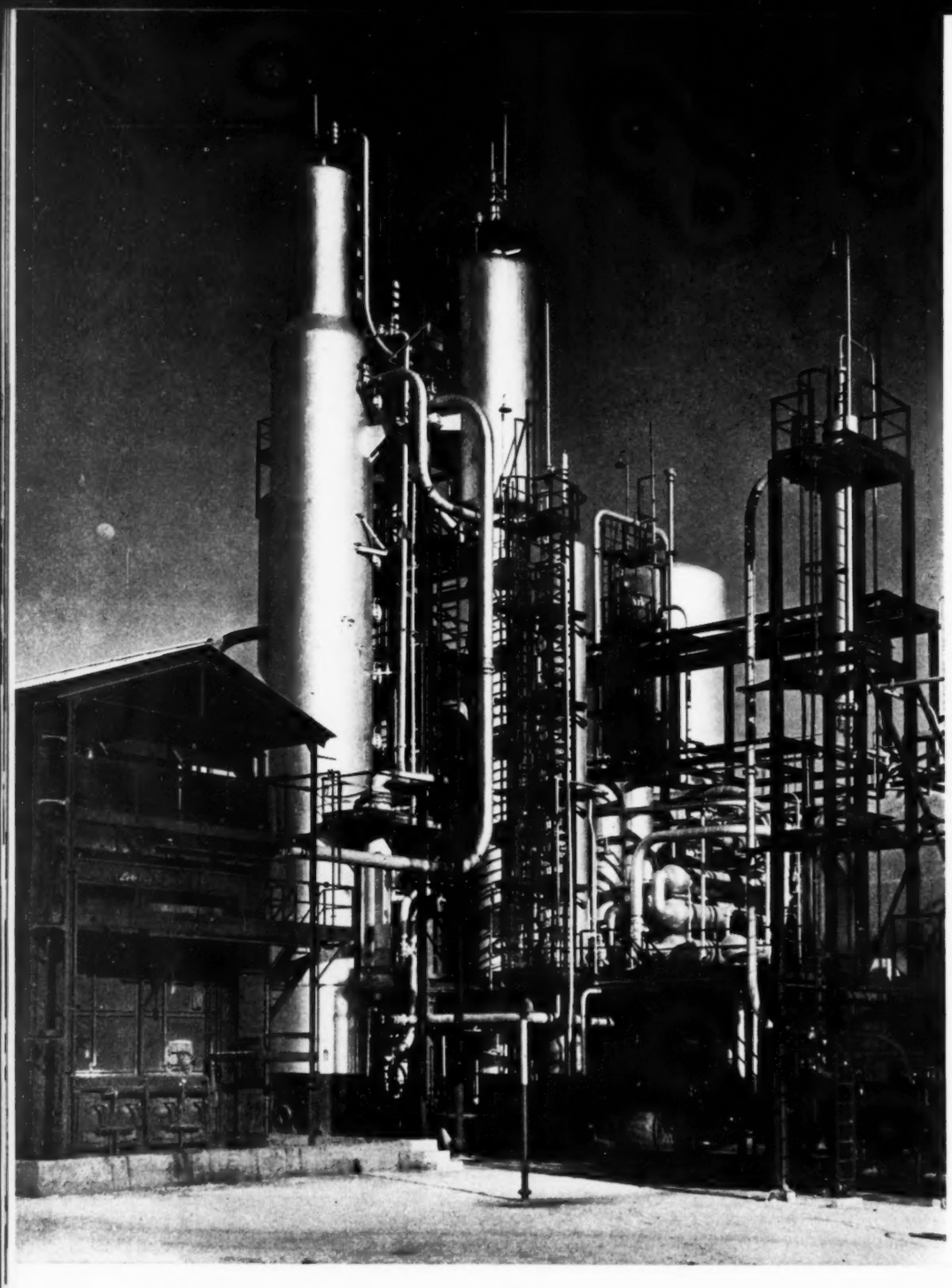
The intangible saving realized from using a corrosion resisting liner instead of ordinary steel can be estimated as follows. The thinning of the carbon steel suction elbows in these pumps is about $\frac{1}{4}$ in. per year, that of 4-6 percent chromium-molybdenum is estimated to be only one-sixth to one-fifth of the thinning of steel elbows. It is reasonable to suppose that 4-6 percent chromium-molybdenum liner will also be five to six times more resistant to corrosion than ordinary forged carbon fluid cylinder.

So far this method has been applied to simplex pumps, if successful in these pumps it may be applied to others.

Credit for developing the method for field heat treatment of air hardening metals and the method for reclaiming pump blocks is due respectively to Mr. S. H. Ransom, Jr., and Mr. C. C. Beal, both of the Port Arthur Works of The Texas Company.

Figure 12—Condemned pump block partly machined after filling with 4-6 chrome alloy.





COST and EXT T

By Eugene R. Smoley, A enr

The Lummus Company

THE present demand for lubricating oils of premium quality far exceeds the supply available from paraffinic base crudes and therefore solvent refining methods for separating constituents of high lubricating value from mixed base crudes have been widely applied during the last few years. The location, operating ownership, and charging capacity of the lubricating oil solvent extraction and dewaxing plants erected throughout the world are listed in Table 1. The rapid increase in the application of these processes is shown by the fact that the total throughput for solvent dewaxing plants has increased by more than 19,000 barrels and that for solvent extraction plants by more than 23,000 barrels in the past two years. For convenience in comparing the various processes, these plants have been arranged so that the total charging capacity and the percent of total installed throughput represented by each process is shown.

The relative advantages of the various solvent refining processes have been rather thoroughly surveyed in the literature and, therefore, no attempt will be made in this paper to compare their performance, economics, or other characteristics. For reference, a tabulation of the significant properties of commercial solvents is included in Table 2. It is the purpose of this paper to present some operating data and cost figures for Furfural extraction and Benzol-Ketone dewaxing. These processes represent the basic steps in lubricating oil refining. Furfural refining serves to remove unstable constituents, carbon forming substances and complex color bodies. Benzol-Ketone dewaxing eliminates waxes which cause solidification of the oil in service. A combination of these processes with clay treatment constitutes a modern method of producing premium grade lubricants.

The commercial success of this process is attested by installations having a total capacity of 26,500 bbl. per day, this figure representing 32 percent of the world's installation of all solvent extraction plants. Stocks handled by the Furfural refining process cover the complete range from very paraffinic, through mixed base, to extremely naphthenic crudes.

Furfural, itself, is an aldehyde prepared from agricultural waste and therefore, a constant supply is assured. Its price has suffered no increase in the last eight years. It is chemically and thermally stable under all operating conditions and undergoes no acid forming reaction in the presence of steam at stripping temperatures; consequently, no discoloration of the oil, or corrosion of equipment, takes place. When charging extremely naphthenic stocks it may be desirable to caustic neutralize the charge stock before running it by any solvent process, in order to prevent corrosion by these naphthenic acids which concentrate in the extract material. Years of experience of users and manufacturers of Furfural prove it has no toxic effect on workers. It lends itself particularly well to the refining of high pour test stocks since extraction takes place at temperatures well above the separation temperature for the wax-oil-furfural mixture. Extraction temperatures range from 150-250 deg. F.

The installation cost of Furfural extraction plants versus their capacity in barrels per day is shown in Figure 1. A basis of normal material specifications and average Mid-Continent labor cost has been taken. The cost of the erected plant will vary somewhat with the solvent ratio required by the charge stock in question, but the curve represents a fair average for reference purposes.

Furfural extraction has lately been applied to the treatment of Western stocks. Operating and performance data for Coalinga, Poso, Kettleman Hills and Ven-

T of Solvent Refining and Dewaxing

A enr y Schutte and H. R. Davis

tura distillates are presented in Table 3. This range of stocks covers waxy and non-waxy distillates, with viscosities from 40-105 S.S.U. at 210 deg. F. The viscosity indices of the treated raffinates range from 25-90. Using representative values for the utilities shown in Table 3, the direct operating cost for Furfural extraction may be calculated. This direct operating cost varies from nine cents per barrel to 12 cents per barrel, depending on the type of operation and the charge stock. These operating costs are quite representative of those to be expected from this process.

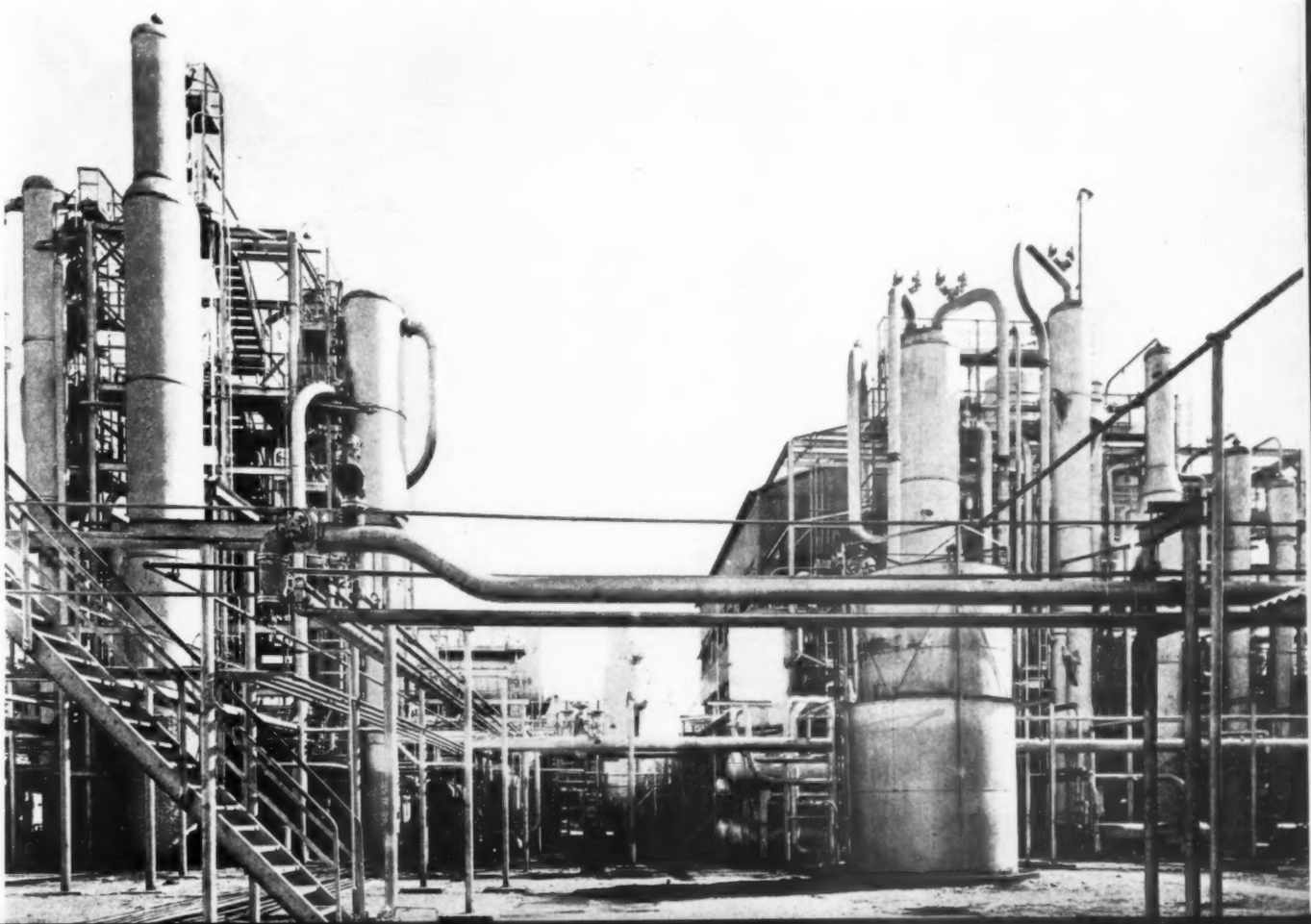
Due to the flexibility of the Furfural treating process all of the stocks shown in the accompanying tabulation can be run in a single plant by simple changes in the solvent ratios and tower extractor operating conditions. The charge throughput will, of course, vary somewhat with the different stocks and operations. The recirculation of extract to the extraction tower provides a further element of flexibility. With a given plant it is possible by extract recirculation to increase the yield of raffinate of a given quality at the expense of some decrease in throughput capacity. This enables the refiner to operate for maximum yield and quality on charge stocks containing fractions of superior lubricating quality.

In contrast to the operation of Furfural extraction on Western stocks, the application of this process to Pennsylvania cylinder stocks is of interest. The development of solvent refining processes has made it possible for the Mid-Continent refiners to prepare a line of premium lubricating oils equalling, and in certain specifications surpassing, conventionally processed lubes of Pennsylvania origin. In order to recapture and maintain his position, the Pennsylvania refiner must ultimately adopt the new processing methods for the dual purpose of increasing the quality of his product and reducing his operating cost. Considerable work has been done on the Furfural extraction of Bradford and other Pennsylvania stocks. This will be but briefly discussed. When charging a 180 viscosity Bradford neutral, each one point increase in viscosity index is obtained with a treating loss of roughly one percent. Conradson carbon is decreased to a nil value, in contrast to the average of 0.04 for a conventionally refined neutral. The color is dropped from 4½ to 2½ on the raw raffinate, and only a very light clay polish is required to increase the color stability and cast.

As in the case of a neutral, a loss of approximately one percent is taken for each point increase in viscosity index when processing Pennsylvania cylinder stocks. The carbon residue of the cylinder stock can be decreased from 2.2 percent to 1.2 percent on the raw raffinate, and after dewaxing and contacting, the carbon residue is further reduced to 0.4 percent-0.6 percent.

The Coubrough process is an improved distillation method for separating resins or asphaltic materials from lubricating oil base stocks. Such materials may be separated either by distillation or by solvent precipitation. Economic studies have shown that Coubrough vacuum distillation equipment can deasphaltize or deresinate a given oil more economically than is possible by the use of solvents. The unusual feature of this process is the use of a close cut petroleum product, such as kerosene or gas oil as a carrier to permit vaporization at a minimum temperature and prevent skin cracking of the oil in the heater tubes. The process has demonstrated its ability to produce low penetration asphalts and high viscosity distillates.

An interesting application is the deresinating of Pennsylvania steam refined cylinder stock to produce a cylinder stock distillate and a high viscosity bottoms product. The data given in Table 5 shows



Top left, Gulf Oil Corporation's furfural refining unit, with 5,000 bbl. per day capacity at Port Arthur, Texas. Right: Magnolia's 3,000 bbl. per day furfural refining plant, and the 3,000 bbl. per day benzol ketone dewaxing unit at Beaumont, Texas.

that Pennsylvania crude may be Coubrough distilled to 1.6 percent bottoms having 1250 viscosity S.S.U. at 210 deg. F. The carbon residue of 9.95 for the bottoms product shows a considerable concentration of this material in the bottoms. If a bright stock is charged, the bottoms may be run to 800 vis. at 210 deg. F. gear lube specifications. Coubrough distillation does not alter the characteristic cast of the cylinder stocks. The approximate operating cost is eight cents per barrel.

methyl ethyl ketone, (b) Benzol and (c) Toluol. Each solvent contributes in its own way towards making a well balanced, flexible dewaxing medium of such a composition that it can be effectively employed in the dewaxing of the full range of stocks normally encountered. Acetone or methyl ethyl ketone is the wax anti-solvent; benzol is employed to increase the solubility of the wax-free oill in the dewaxing agent. Toluol is used to lower the freezing point of benzol in the mixture to a temperature below that at which filtration is carried out.

The solvent mixture employed boils over the range of 175 deg. F. to 231 deg. F. under atmospheric pressure. Solvent recovery can thus be economically effected with live steam as a heating medium without the use of vacuum equipment. Because of the thermal and chemical stability of the solvents, no deterioration of the solvent or corrosion of the equipment takes place.

Since the pour test is normally dependent on the residual wax, the low solubility of wax in the ketone-benzol solvent, shown in Table 2, results in a very small spread between filtration temperature and pour test. In practice, it is found that Benzol-Ketone dewaxing of Bradford cylinder stock at —15 deg. F. produces zero cold test oil. The cloud test is identical with the cold test.

The results obtained are practically independent of chilling rate. It is therefore, possible to take full advantage of the new type of scraped-surface heat exchangers and chillers having high coefficients of heat transfer. Batch chillers are unnecessary and therefore a large hold-up of solvent and oil in the system is eliminated.

Filtration of all stocks takes place without the use of filter aids or crystal modifiers. This condition results in three distinct advantages.

(1) There is no operating cost for expensive modifying agents which are lost in the wax stream.

(2) Wax distillates can be filtered without the addition of petrolatum as a cake modifier. Consequently, the slack wax in a neutral cake can be sweated directly without resorting to a preliminary distillation for the segregation of petrolatum.

(3) In the case of cylinder stock, certain operating advantages result from the recycling of part of the wax or the deliberate addition of petrolatum. It is possible, in this way, to work off any accumulation of petrolatum resulting from previous re-

TABLE 1

Lubricating Oil Solvent Extraction Plants

Furfural Process

COMPANY	LOCATION	CHARGING (BBL/DAY) CAPACITY
Gulf Oil Corp.	Port Arthur, Texas	5,000
Indian Refining Co.	Lawrenceville, Ill.	1,300
The Texas Co.	Port Arthur, Texas	6,000
Shell Ref. Ltd.	England	1,650
Elwerath	Germany	1,700
Photogen Rafinerie de Petrol	Roumania	100
The Magnolia Petroleum Co.	Beaumont, Texas	3,000
Irish Nat. Ref.	Dublin, Ireland	1,400
Trinidad Leaseholds	Pointe-a-Piero, Tr.	2,910
Shell Oil Co.	Martinez, Cal.	3,250
		26,510—31.78%

Duo Sol Process

Gulf Oil Corp.	Girard Point, Pa.	2,500
Magnolia Petroleum Co.	Beaumont, Texas	2,800
The Socony Vacuum Oil Co.	Paulsboro, N. J.	3,000
The Herbert Green Co., Ltd.	England	1,500
Deutsche Vacuum Oel, A.G.	Germany	1,000
Raffinaria di Napoli, S.A.I.	Italy	750
Raffineries de la Vacuum Oil Co. S.A.F.	France	750
Shell Petroleum Corp.	Wood River, Ill.	3,000
Standard Oil Co. Cal.	Richmond, Cal.	3,300
		18,800—22.54%

Phenol Process

Standard Franco-Americaine de Raffinage	France	3,500
Imperial Oil Co., Ltd.	Sarnia, Canada	2,000
The Standard Oil Co. N.J.	Bayonne, N. J.	1,000
The Standard Oil Co. N. J.	Baton Rouge, La.	5,000
The Standard Oil Co. Cal.	California	3,500
		15,000—17.98%

SO_2 Benzol Process

Tide Water Associated Oil Co.	Avon, Cal.	1,500
The Shell Oil Co. of Cal.	Richmond, Cal.	1,500
The Union Oil Co.	Oleum, Cal.	1,500
Lobitas Oilfield, Ltd.	Ellesmereport, Eng.	500
Rhenania Ossag	Hamburg, Germany	1,750
Anglo Iranian Oil Co.	Llandarcy, Eng.	1,600
The Texas Co.	Port Arthur, Texas	1,000
Tide Water Associated Oil Co.	Bayonne, N. J.	2,000
"Aguila" SATI	Trieste, Italy	700
Manchester Oil Ref.	Manchester, Eng.	700
		12,750—15.29%

Chlorex Process

Standard Oil Co. Indiana	Wood River, Ill.	1,000
Freedom Oil Works	Freedom, Pa.	1,200
Pennzoil Co.	Pennsylvania	1,000
Mid-Continent Petroleum Co.	Tulsa, Okla.	200
Standard Oil Co. Indiana	Wood River, Ill.	1,000
Socony Vacuum Oil Co.	Olean, N. Y.	1,700
Standard Oil Co. Indiana	Casper, Wyo.	600
Bradford Penn. Ref. Co.	Clarendon, Pa.	500
		7,200— 8.63%

Nitrobenzene Process

Atlantic Refining Co.	Phila., Pa.	2,350
The Sinclair Refining Co.	Wellsville, N. Y.	800
		3,150
TOTAL		83,410—100%

Solvent Dewaxing Plants

Benzol Ketone Process

COMPANY	LOCATION	CHARGING (BBL/DAY) CAPACITY
Indian Refining Co.	Lawrenceville, Ill.	1,400
Atlantic Refining Co.	Philadelphia, Pa.	600
Gulf Oil Corp.	Port Arthur, Texas	1,500
Herbert Green Co.	East Halton, Eng'd	1,000
Deutsche Vacuum Oel A.G.	Bremen, Germany	525
Raffineria di Napoli, S.A.I.	Naples, Italy	525
Socony Vacuum Oil Co.	Paulsboro, N. J.	3,800
Shell Refineries, Ltd.	Shell Haven, Eng'd	1,200
Gewerkschaft Elwerath	Misburg, Germany	1,200
The Texas Co.	Port Arthur, Texas	3,750
S. A. Petrofina	Dunkerque, France	500
Quaker State Refining Co.	Pennsylvania	1,500
Socony Vacuum Oil Co.	Olean, N. Y.	1,800
Magnolia Petroleum Co.	Beaumont, Texas	3,000
Bradford Oil Refining Co.	Bradford, Pa.	600
Tide Water Associated Oil Co.	Bayonne, N. J.	1,050
Standard Oil Co. Cal.	Richmond, Cal.	1,500
Irish National Ref.	Dublin, Ireland	1,000
Photogen Rafinerie de Petrol	Brasov, Roumania	100
Rhenania Ossag	Hamburg, Germany	1,200
Sinclair Refining Co.	Wellsville, N. Y.	3,500
		31,250—62.7%

The Propane Process

Standard Oil Co. Indiana	Wood River, Ill.	1,300
Union Oil Co.	Oleum, Cal.	1,300
Shell Petroleum Co.	Wood River, Ill.	2,400
Bradford Penn. Refining Co.	Warren, Pa.	250
Kendall Refining Co.	Bradford, Pa.	1,200
Humble Oil Ref. Co.	Baytown, Texas	3,400
Standard Oil Co. La.	Baton Rouge, La.	2,000
		11,850—23.8%

SO_2 Benzol Process

"Aguila" SATI	Trieste, Italy	450
Anglo Iranian Oil Co.	Llandarcy, Eng.	1,600
Lobitas Oilfield, Ltd.	Ellesmereport, Eng.	350
Manchester Oil Ref.	Manchester, Eng.	450
		2,850— 5.7%

The Barisol Process

The Standard Oil Co. La.	Baton Rouge, La.	1,800
The Continental Oil Co.	Ponca City, Okla.	400
		2,200— 4.4%

Other Processes

Imperial Oil Co.	Sarnia, Canada	1,000
Standard Franco Americaine	Port Jerome, France	700
		1,700— 3.4%
TOTAL		49,850—100%

Installations of the Benzol-Ketone process have a total capacity of 31,250 bbl. per day, or about 63 percent of the world's solvent dewaxing capacity. In the Pennsylvania region they aggregate a capacity of 8,000 bbl. per day and represent about 85 percent of the total installed dewaxing capacity.

This process employs a mixture of three commercial grade solvents: (a) Acetone or

TABLE 2

Properties of Commercial Solvents

Solvent	Sp. Gr.	Boiling Point deg. F.	M.W.	Solubilities at 100 deg. F. Solvent in Water (Weight	Water in Solvent percent)	B.P. of Constant-Boiling Mixture deg. F.	Compn. of Constant-Boiling Mixture Overhead Wt. percent Solvent	Solubilities of 123 deg. F. M.P. wax 0 deg. F. gm/100 cc
Acetone	0.792	133	58.1	....	....	None	None	....
Aniline	1.022	364	93.1	3.8	5.6	209	23.1	....
Benzene	0.878	176	78.1	0.16	0.11	None	None	....
Carbon tetrachloride	1.584	170	153.8	0.09	0.01	None	None	....
Chlorex	1.222	353	143.0	1.2	1.1	204-7	....	....
o-Cresol	1.051	375	108.1	3.0	14.5	210	6	....
m-Cresol	1.039	396	108.1	2.5	14.5	210	6	....
p-Cresol	1.039	396	108.1	2.2	16.5	210	6	....
Ethylene dichloride	1.257	182	99.0	0.9	....	158	91.8	....
Furfural	1.162	323	96.0	9.0	6.5	208	35	....
Methyl ethyl ketone	0.805	175	72.1	19.0	10.2	164	88.6	....
Nitrobenzene	1.207	412	123.5	0.3	0.35	211	15.3	....
Phenol	1.072	358	94.1	9.4	32.5	210	9	....
Propane	0.511	—48	44.1	3.4	....	None	None	0.06
Sulfur dioxide	1.45	14	64.1	....	....	None	None	....
Toluene	0.866	231	92.1	0.05	....	None	None	0.08
Trichloroethylene	1.480	188	131.4	0.16	0.05	167	....	....
Naphtha	....	....	90	....	....	....	....	0.21
65 Percent Benzol 35 Percent Acetone								0.009

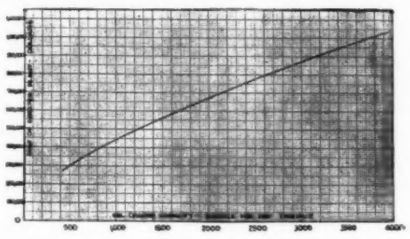


Figure 1

Installation costs of a furfural extraction plant.

the following directly comparable data on the single cycle sweating of: 1. conventionally prepared slack wax obtained by cold pressing; 2. slack wax obtained by Benzol-Ketone dewaxing regular wax distillate; and, 3. slack wax obtained by Benzol-Ketone dewaxing regular wax distillate which had been previously reduced to 140 neutral.

It will be noted that the amount of scale wax obtained from the reduced distillate amounted to more than twice

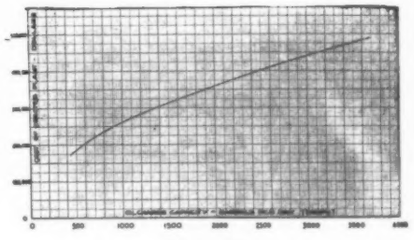


Figure 2

Installation costs of a benzol ketone dewaxing plant.

TABLE 3

Furfural Treating Western Stocks—Operating and Performance Data

	Coalinga Distillate 85/210	Coalinga Distillate 40/210	Poso Distillate 85/210	Poso Distillate 85/210	Poso Distillate 105/210	Kettleman Distillate 105/210	Ventura Distillate 55/210
Charge Inspections							
Gravity, °A.P.I.	16.2	19.5	16.2	16.2	15.5	19.5	21.9
Flash, °F.	430	355	435	435	455	525	415
Fire, °F.	470	.....	490	490	.....	605	485
Vis. @ 100°F., S.S.U.	2235	206	2315	2315	3844	2400	420
Vis. @ 210°F., S.S.U.	85	41	84.3	84.3	104	105	54.4
Color, Tag. Rob.	1½	1¾	.....	.....	.....	.....	.....
Pour Test, °F.	+15	Below —25	+15	+15	.....	+85	95
V.I. (D and D)	minus 36	minus 110	minus 51	minus 51	minus 61	40 waxy	63 waxy
V.G.C.	.....	.....	.....	.....	.....	0.870	0.870
Pff. Wax, % by wt.	0.3	0.02	.....	.....	.....	.....	.....
Charge Thruput, B/D	2210	2230	2150	3295	3420	.....	.....
Raffinate Yield, Vol. %	51.0	49.5	41.0	70.0	68.0	50.0	42.0
Raffinate Inspections							
Gravity, °A.P.I.	25.2	28.0	26.0	21.8	21.3	.....	32.3
Flash, °F.	445	360	435	.....	440	.....	435
S.U.V./100°F.	698	137	690	1 030	1488	.....	179
S.U.V./210°F.	65.2	41	64.4	70.0	82.1	.....	48
V.I.	61	.....	60	25	25	.....	133 waxy
V. I. (dewaxed)	.....	.....	.....	.....	.....	90	90
Color (Tag Robinson)	.....	3½	3½	6	.....	.....	.....
Extract Inspections							
Gravity, °A.P.I.	7.6	12.6	9.6	4.4	4.4	.....	.....
Flash, °F.	440	345	435	.....	415	.....	.....
S.U.V./100°F.	.....	380	275/130	.....	1821/130	.....	.....
S.U.V./210°F.	160	46	.....	218	.....	.....	.....
Furfural Treat, Vol. %	300	300	350	110	130	350	300
Utility Consumption							
Live Steam, #/Hr.	1500	1600	.....	1790	1790	.....	.....
Electricity, K. W.	97	85	.....	85	86	.....	.....
Gas Fuel, C.F.H.	18120	13000	.....	12800	10100	.....	.....
Cool'g Water, GPM 85°F.	1180	1180	.....	1029	1130	.....	.....
Furnace Efficiency, %	72	78	.....	75	76	.....	.....

finery operation, or deoiling of petrolatum may be carried out as a completely separate operation. Thus one refiner has been able to work off considerable quantities of accumulated petrolatum carried at cracking stock value and to obtain therefrom a yield of 40 percent of zero degrees F. pour bright stock. A similar operation is practiced in the Benzol-Ketone dewaxing of 80 pour Pennsylvania foots oil accumulated from previous cold pressing operation, this operation resulting in the reclamation of 55-57 percent of 90 vis/100 20 pour light oil.

When dewaxing distillates containing sweatable wax it is not necessary to handle a stock of normal pressing viscosity. Operation of the crude distillation unit may be adjusted to exclude gas oil from the sweatable wax bearing crude fraction. The total quantity of distillate dewaxed is thereby reduced and the rerunning of a pressed cut completely eliminated.

The best evidence of the success of Benzol-Ketone dewaxing of wax distillate is seen in the discontinuation of cold pressing by those Pennsylvania operators having Benzol-Ketone plants. The results obtained by these operators are typified in

TABLE 4

Benzol-Ketone Dewaxing Pennsylvania Stocks

Charge Inspections	Cyl. Stock	Wax Dist.
Grav., °A.P.I.	25.9	33.3
Flash, °F.	570	390
Vis. @ 210°F., S.S.U.	149	40
Vis. @ 130°F., S.S.U.	855	64
Pour, °F.	50	80
V.I.	103	138
Pff. Wax, % wt.	13.0	15.5
Thruput, B/D	1220	1850
Pressed Oil Yield	90.0	83.0
Pressed Oil Inspections		
Grav., °A.P.I.	25.3	31.2
Flash, °F.	565	390
Vis. @ 210°F., S.S.U.	157	40.5
Vis. @ 130°F., S.S.U.	2597	116
Pour	10	zero
Wax Inspections		
Grav., °A.P.I.	33.3	41.5
Vis. @ 210°F., S.S.U.	105	37
M.P., °F.	133	114.5
Utilities, per 42 gal. bbl. charge		
190# steam, lbs.	222	170
150# steam, lbs.	123	94
KWH	10.1	7.7
Water, 80°F., gals.	1455	1110
Direct Operating Cost, Cents/Bbl.		
190# steam, (20c/1000#)	4.44	3.40
150# steam, (20c/1000#)	2.46	1.88
Electricity, (0.5c/KWH)	5.05	3.85
Cooling Water, (50c/1000 B)	1.70	1.30
	13.65	10.43
Solvent Loss	3.40	3.90
Labor	7.70	5.10
Maintenance	2.40	1.60
TOTAL	27.15	21.03

that obtained from regular plant slack wax. Further, the average melting point of the scale wax was over ten degrees higher in the case of the slack wax obtained by the Benzol-Ketone process.

Due to the decreased oil content of the solvent prepared slack wax a considerable reduction in resweating operation is found attending an increased yield of higher melting point products. Sweater yields of 50-60 percent of finished wax are thus obtained.

Comparative Dewaxing Results

Source of Slack Wax		Conventionally Processed Wax Dist. (Percent)	Benzol-Ketone Dewax'g of Reg. Wax Dist. (Percent)	Benzol-Ketone Dewax'g of 140 Neutral (Percent)
Foots Oil	(Start to 100 deg. F. M.P.)	60.0	19.5	15.0
Intermediate	(From 100 deg. F. to 110 deg. F. M.P.)	6.0	29.5	10.0
Scale Wax	(100 deg. F. M.P. to off)	33.5	51.0	75.0

Typical plant operating data on Benzol-Ketone dewaxing of Pennsylvania cylinder stock and wax distillate is shown in Table 4. The utility consumption for these two stocks is listed and direct operating cost calculations shown. The direct operating costs of 21c per barrel charge oil when running wax distillate and 27c per barrel for cylinder stocks show the operating economy of this process. The newer Benzol-Ketone dewaxing plants have lower operating costs due to the use of improved methods of solvent recovery.

A curve showing the installation cost of Benzol-Ketone dewaxing plants versus the charge oil throughput is presented in Fig. 2. A basis of average Mid-Continent labor costs and material specifications of the usual quality, has been taken. The plant cost will vary with the solvent ratio required for the various stocks, but for reference purposes, the values shown are representative.

TABLE 5

Cout rough Vacuum Deresinating Pennsylvania S. R. Cylinder Stock

Inspections	Cyl. Charge	Stk. Side Product	Bottoms Product
Grav., °A.P.I.	25.7	26.5	20.1
Vis. @ 210° F., S.S.U.	156.4	103.4	1250
V. G. C.	0.813	0.815	0.829
Flash, C.O.C., °F.	555	550	685
Pour, °F.	40	50	.....
Color	6-95/5	7½ Dil.	.....
Carbon Res.	2.5	1.96	9.95
Furol Vis. @ 210° F.	.....	.....	128
Yields			
Vol. % on Charge	100.0	91.6	8.4
Vol. % on Crude	19.0	17.4	1.6

PROBLEMS OF PETROLEUM REFINING

Challenge Resources of

Engineering Organization of International Scope

Of the mechanical advances that have revolutionized the oil industry, both in production and processing, the greater number have come from the experience, research and experimentation of the manufacturers of oil industry equipment. This is not surprising because the business of these companies depends upon constant progress in the quality of materials and machinery and in the development of more efficient and more economical methods of performing the myriad tasks set by this highly competitive industry.

Most of the fundamental problems of refining are concerned with applications of heat and pressure. Consequently it is not strange that commercial organizations with a background of accumulated experience and information in heat engineering should have been drawn to the field of petroleum refining, first by the rapid expansion of the refining business, and, second, by the nature of the problems it presented. The following article describes the part played by one such organization in the forward progress of the refining industry in all parts of the world during the past thirty-four years.

In 1920 there was not a single high pressure, high temperature cracking heater in service in the world, operating in an efficient and dependable manner. The cause of difficulty was consistently the same—overheating. Overheating the oil caused accumulation of coke, accumulation of coke caused hot spots in the tubes; and the hot, burned tubes succumbed to pressure. Great was the variety of design brought into service in the effort to overcome tube failure in cracking service—but to no avail.

Late in that year a branch office of Power Specialty Company (now Foster Wheeler Corporation) received a call from one of the large refiners for a conference on cracking heaters. Power Specialty Company was a newcomer in the petroleum equipment field but had surprised refiners with distillation heaters that performed way out bounds, when measured by existing standards. But it had never built a cracking heater.

The proposition as put was: could a heater be made theoretically, "hyperthetically" was the actual word used—that would be capable of adding 10,000,000 B.t.u. per hour; (many hundred percent more than any heaters of record in service at that time). The branch office wired headquarters and was back within 48 hours with an affirmative reply. Something seemed to have gone wrong; there was no enthusiasm by the refinery engineers. Finally they admitted that they were much interested but would have to be convinced through drawings, heat absorption rates, oil velocities, etc.

The design was developed, checked, approved the heater ordered and built. It had a large furnace with a high bridgewall at the back and behind this were rows of horizontal heating tubes covered with cast iron, extended surface rings. Gases flowed over the top of the bridge wall, down past the heating surface, and to the stack through underground flue. This arrangement shielded the heating elements from the direct glare of the furnace—radiant heat—and limited the heating effect to convection from the hot gases. Power Specialty company had learned this trick years before in the deodorizing of vegetable oils that were very sensitive to overheating. In operation, the new furnace was supplied with a high percentage of excess air to cool

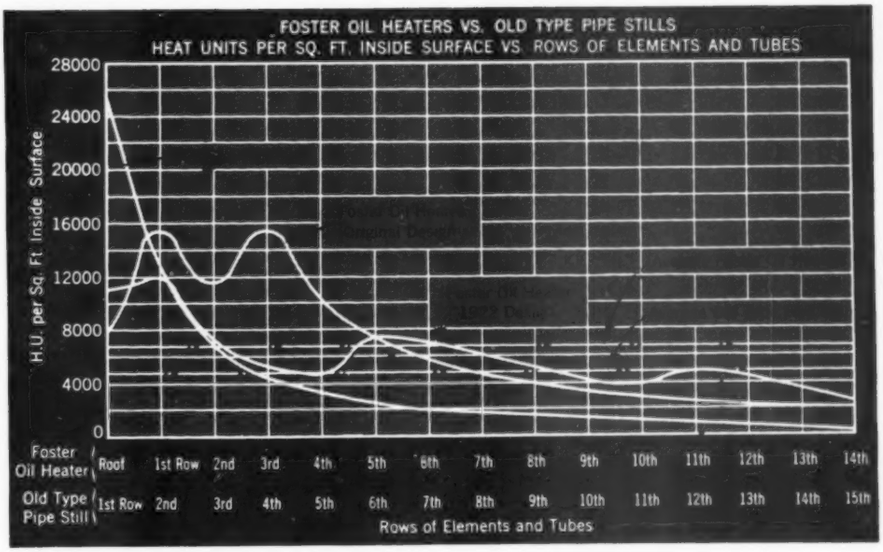
it and reduce the gas temperatures entering the heating chamber. All guarantees were met; were greatly exceeded in fact.

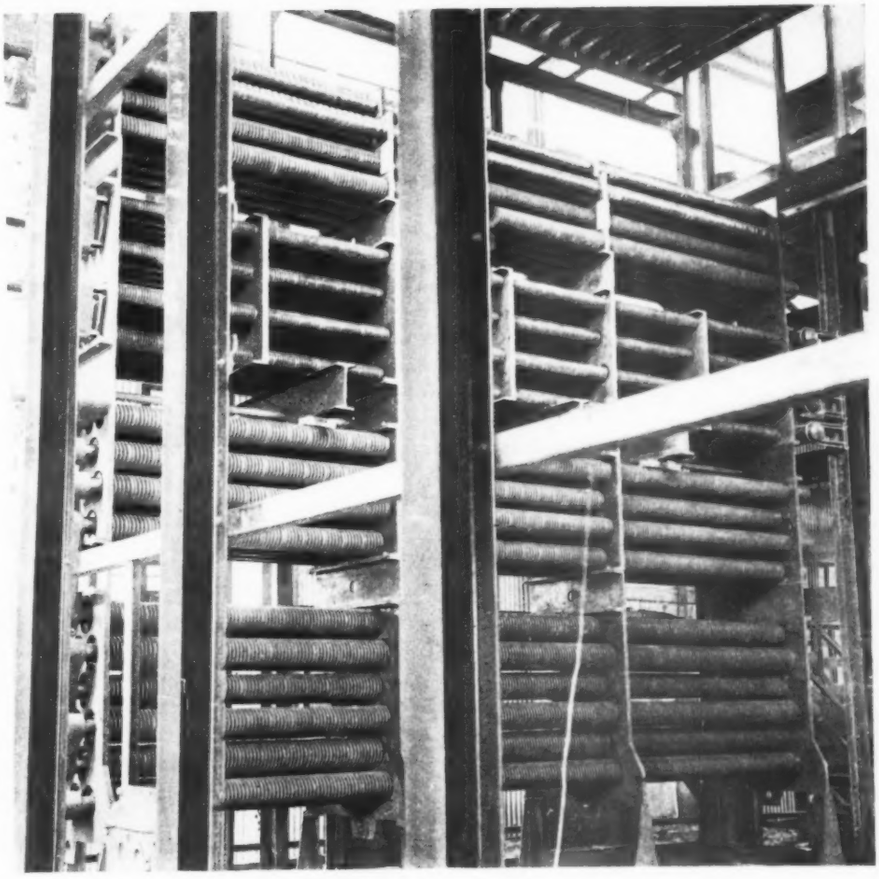
So easily had this been done, and with such absence of stress on the heater that the refinery engineers wanted to go farther; to do more; to increase efficiency; to find out what the limitations of the new creation really were. They were planning on a battery of 10 units and before ordering the other nine wished to explore the possibilities thoroughly. The company's chief engineer went to the refinery, made studies and investigations of heat transfer, combustion conditions and heat balances. He developed a roof for the heater composed of oil heating tubes. These would be swept only slightly by the hot gases but would be exposed directly to the radiant heat of the furnace.

Thus was first demonstrated to the petroleum industry the fundamental principle of segregating the absorption of heat by radiation and by convection. For the first time it was possible to control the absorption of heat in a cracking furnace within limits of safe and continuous operation. This control was definite and, by design, the absorption per square foot could be reduced within acceptable limits—whereas previously the designs had been attempts to create a structure so massive that it would withstand the terrific overheating, beyond anyone's control.

Now, also for the first time, cracking heaters were placed on a basis of efficient combustion. The CO_2 was at once raised materially and additional improvement followed. The remodeled heater had an efficiency of 62½ percent, a fuel saving of 18 percent, and was unquestionably an historic milestone in petroleum refining. Nine additional units followed its design. Quickly heaters of varied designs sprang up in every direction, all taking advantage of the principle of controlling radiant heat. Cracking—an experiment—was made an assured success and many difficult heating processes became practical and profitable.

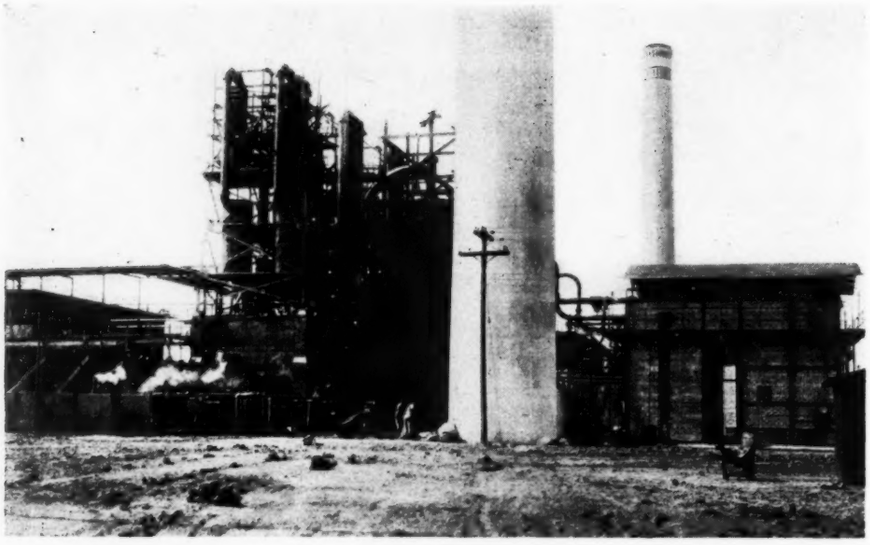
About this time there came to light the inescapable touch of humor in a serious undertaking. When the refinery engineers had given their "hyperthetical" conditions for the heater requirements, they had asked for just twice as much as they needed, and twice as much as they figured was possible. This was to be a means of judging the conservativeness of Power Specialty engineering. If it objected to the excessive requirements the refinery would recognize good judgment and go along, confident that it was in good hands. The reply of the branch office men, that they were authorized to guarantee the suggested conditions in full, confused the refinery engineers who wondered which side could have erred so badly in its estimates.


FOSTER OIL HEATERS VS. OLD TYPE PIPE STILLS
HEAT UNITS PER SQ. FT. INSIDE SURFACE VS. ROWS OF ELEMENTS AND TUBES
H.U. per Sq. Ft. Inside Surface
28000
24000
20000
16000
12000
8000
4000
0
Foster Oil Heater
Roof 1st Row 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th
Old Type Pipe Still
1st Row 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th 15th
Rows of Elements and Tubes



A battery of four tubular furnaces (facing page) built for the Atlantic-Gulf and West Indian Oil Company at Tampico, Mexico. Fourteen of these stills were erected in 1919 and 1920 at this refinery and according to latest reports they are still in service. (Top) This curve, published first in 1922, gives the basic data from which modern tubular furnaces were developed. Just below are shown the heat absorbing elements of a modern tubular furnace. Various types of extended surface heating elements are shown on the right.

Heat transfer was the strong point of Power Speciality Company then, as it is of Foster Wheeler today. For 20 years previously the company had been engaged in pioneering work of superheating steam in this country, in building destructor plants for burning municipal waste, in developing high pressure economizers for power plant



Above, one of two fractional distillation units erected in 1923 at the Smiths Bluff, Texas, refinery of Humphrey's Pure Oil Company. These were the first single flash petroleum fractionation units and this was the first refinery to depend entirely on tubular furnaces for heating. Below, one of the first Foster Wheeler tubular furnaces erected in the Iranian desert.

boilers, and in production of chemical processing equipment; including indirect oil heating systems. In these systems the oil heated by direct firing was circulated to jacketed vessels, or through coils, to heat sensitive fluids without danger of over heating. Before the oil industry had become an important field for Power Specialty's engineering, it had raised superheated steam to 1,250 deg. F.; chemical gases to 1,100 deg. F. and 4,500 lb. per sq. in. pressure; and built destructor furnaces approaching 2,800 deg. F. They had developed economizers recovering great quantities of heat from stack gases ordinarily wasted to atmosphere.

These experiences reach limits well beyond petroleum refining requirements, even of today, and placed Power Specialty Company in a unique position to render service to the refining industry.

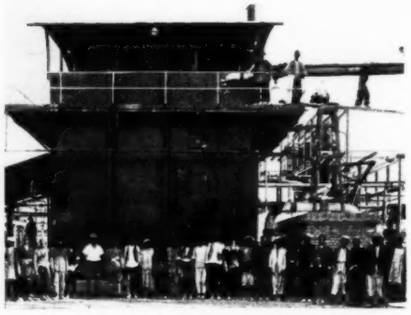
On November 17, 1903 a patent was issued covering application of extended surface castings to steel tubes. This composite construction for heating elements was to prove of fundamental importance especially in recovery of heat from gases at moderate temperatures, and in protecting steel tubes from rapid deterioration. Iron castings have been used, generally, both because of low cost and extremely high resistance of cast iron to corrosion. With such a construction it was possible to graduate the heat absorbing area on the exterior of a tube to correspond with the reduction in temperature and volume of gases as they give up heat in passing through the bank of heating elements.

It is practicable to start with cylindrical covering followed with tubes having corrugated rings—increasing the heat absorbing area to 160 per cent of that of the bare tube. Next would come a standard gilled ring casting presenting 400 percent of the area of the bare tube, and last of all would be the largest size of gilled ring presenting six times the surface of bare tubing.

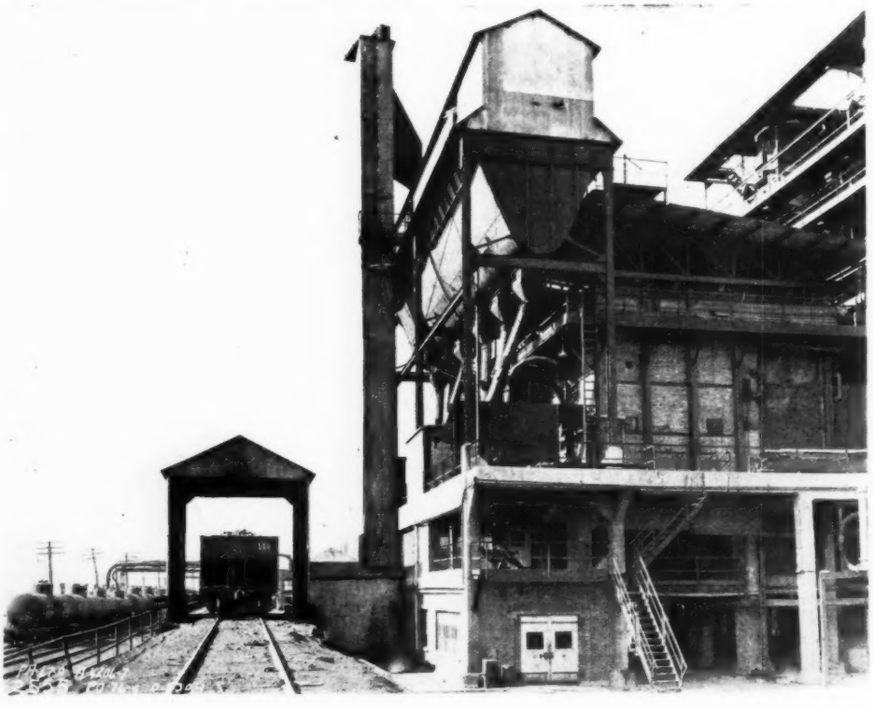
This provides a mechanical graduation of the heat absorbing area over which the gases pass without increasing the number of tubes carrying the fluid to be heated and without changing their diameter. Obviously, such a result can hardly be obtained in any other manner and this graduation in heat absorbing rate provides a more effective utilization of heating surface as the gases cool and the fluid heats, than would otherwise be practicable.

Employing the principles of the composite element, steady progress was made in the solution of heat transfer problems including superheaters applied to boilers, separately fired superheaters, separately fired air heaters and heaters for various chemical processes. This activity eventually led to their use by a packer of sardines in the heating of packing oil. A number of direct fired oil heaters were sold to manufacturers of edible oils, including cottonseed oil. Production of synthetic butter from coconut and peanut oils presented specific and exacting requirements.

The problem was to heat the oil sufficiently to effect deodorization by driving



Below, two tubular heaters at the Franklin, Penn., plant of the Atlantic Refining Co. fired by pulverized fuel since 1926.



off free fatty acids and other objectionable ingredients. The oil mixture, however, was sensitive to heat and discolored quickly when limiting temperatures were exceeded. Discoloration ruined the product as it had to be virtually water-white in order to be saleable.

A modification of the cottonseed oil heaters was developed and by constructing a combustion chamber for producing hot gases, and segregating it from the chamber containing the heating tubes, it was possible to effect entirely satsifactory operation through the introduction of excess air to cool the furnace as the temperature of the circulated coconut oil approached the prescribed limit.

Furnace design had become one of the chief factors in the success of the Power Specialty Company and it had gained wide experience with a variety of fuels.

The next logical step was the application of these heaters to petroleum refining. This type of heater belonged in the oil refinery: Power Specialty Company possessed the background and experience to adapt such heaters to refining.

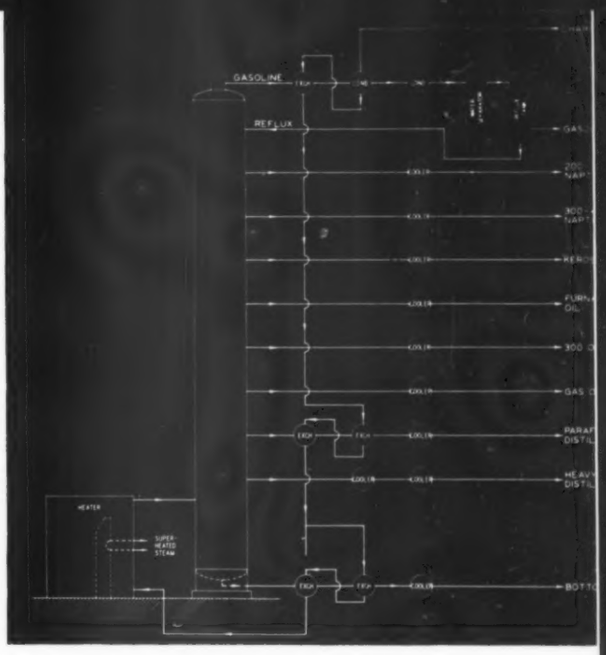
But at this time, oil refiners fearful that competitors would profit by knowledge painfully acquired, preferred to work secretively and shrouded their operations in much mystery. Some refiners had attempted to use extended surface elements in oil heaters of their own design. For the most part, however, they overlooked the fact that the "closed door" barred out progressive ideas quite as effectively as it shut in those that they had developed. Not until 1915 was the first oil heater incorporating all Power Specialty's advanced ideas on furnaces installed in an oil refinery. Records show that this heater was still in service as late as 1932.

In 1919, four tube stills were designed and installed to meet the specific requirements of a refiner in Mexico for fractional distillation. These heaters were patterned closely after the separately fired steam superheaters and included a row of oil heating tubes in the roof of the furnace for the purpose of providing a permanent construction to replace firebrick arches of relatively short life, and to reduce greatly the deterioration of furnace brickwork. This was actually the first segregation of radiant and convection heat in tube still operation but its full advantage was not appreciated at that time and the scientific engineering determination of the requirements and use were worked out on the cracking heater previously mentioned. In this case the heaters followed separately fired superheater practice and the service was not sufficiently severe to create the problem later encountered. These four heaters, however, are still in satisfactory service, according to latest information.

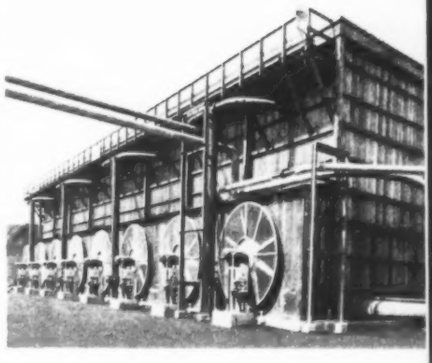
Following the successful operation of these heaters, the demand for such tubular oil stills grew at a rapid rate. Experience gained with them, and with cracking heaters, resulted in ability to predict operating conditions precisely and, therefore, the construction of a great variety of sizes for highly different operating conditions and crudes, with certainty as to the outcome.

As was to be expected, gradual improvements were incorporated, and units of tremendous capacity constructed. The proportion of radiant heat absorbing surface has increased steadily until, in some phases of refining the amount of radiant heat surface is more than that of convection. As experience was gained the application of radiant heat absorbing surfaces that had been avoided in earlier furnaces due to overheating through subjection to heat by convection, progressed in rapid strides.

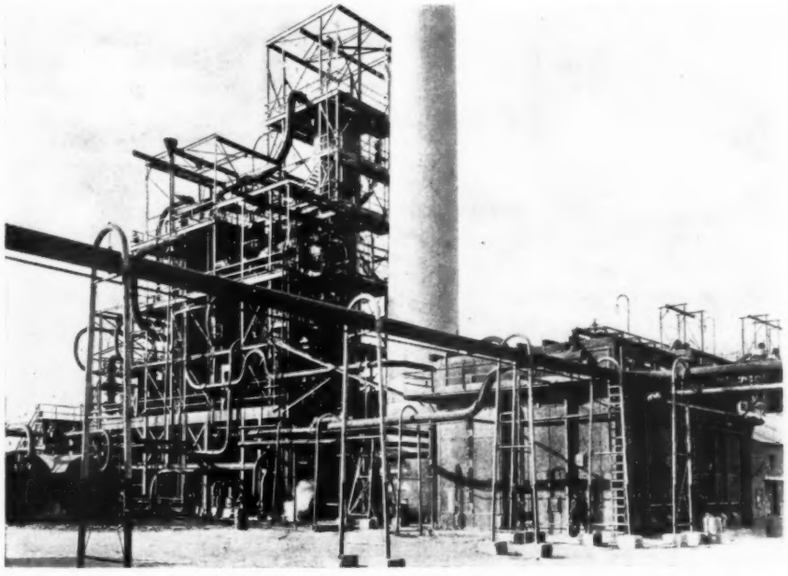
The first cracking heater fully described above had proved that the more radiant surface in a furnace the lower the rate of heat transfer per square foot because of lower furnace temperature. This greatly increased the life of radiant heating tubes and by 1925 furnaces were operating with seven to eight square feet of radiant heating surface per gallon of fuel oil burned, and 60-70 percent of the total heat input

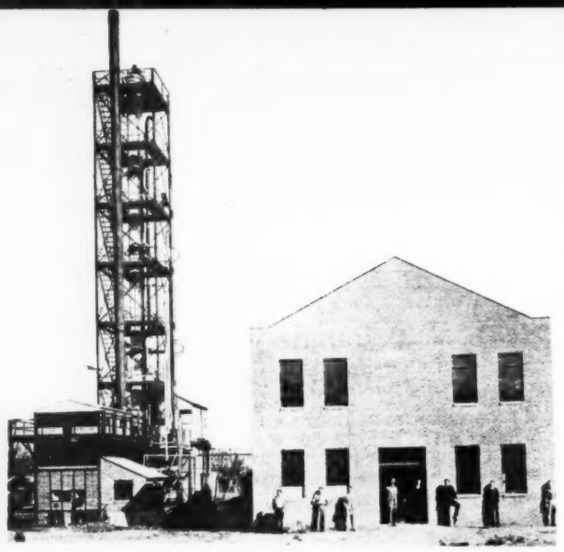


Top, flow diagram showing operation of 7,500 bbl. per day atmospheric distillation unit. Right, large forced draft cooling tower containing sixteen Axial Flow type fans. Below, world's largest atmospheric type cooling tower 2,000 ft. long.



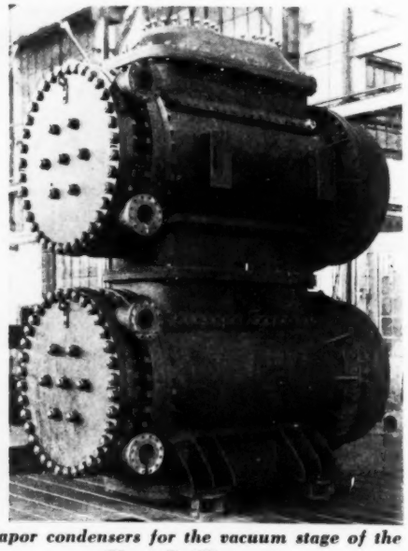
Below, an early single flash fractionation unit for the continuous distillation of crude to lighter fractions and lubricating stocks in a single operation. This unit was installed at the Ponca City, Okla., plant of the Rarland Refining Co.





Experimental single stage fractionating unit of 200 bbl. per day capacity at the University of Oklahoma.

Early two-stage single flash fractionating unit (left) shown beside the old style battery it replaced at the Olean, N. Y., refinery of Socony-Vacuum Oil Co.



Vapor condensers for the vacuum stage of the Olean distilling unit.

to the oil was being absorbed in the radiant section. Some furnaces have been built entirely with radiant heat surface for special conditions. Notable among improvements was the use of special alloys within the furnaces. This involved not only the heating tubes but tube supports and hangers subjected to high temperature, return bends and parts of the setting. Time on stream was greatly increased and production costs reduced correspondingly.

As an example of the tremendous impetus given the refining industry, the effect of a heater designed in 1922 for the special process of a specific refiner is interesting. After testing the heater extensively, orders were placed for 87 additional heaters in affiliated refineries throughout the country. Altogether in that year 110 tubular oil heaters were furnished the industry. This is a striking example of the result of placing confidence in a specialist in his line and cooperating with him for a definite objective.

The Power Specialty Company had entered refining work at a logical time, namely, when great dissatisfaction was being experienced with shell stills, due to their decided limitations, and when great difficulty was being experienced in creating tubular stills of satisfactory endurance and efficiency; in other words, at the period of one of the greatest changes in refining methods, the transition from shell stills to tubular stills. Performances of pipe stills were so good that they attracted the attention of refiners generally and rapid impetus was given to their displacement of shell stills.

The next step of impressive consequences took place when a large refinery was laid out with pipe stills exclusively to conform with the newest practice. That was the first refinery to abandon entirely shell stills and to rely solely on tubular construction for all processes from low pressure distillation to cracking. The capacity was 10,000 bbl. per day, divided between two 5,000 bbl. units, the heater being designed to heat the charge to 850 deg. F. This was considerably higher than previous practice but used in order to produce gas oil overhead as charging stock for the cracking units, in addition to gasoline and kerosene. Modern practice was also reflected in the use of heat exchangers and fractional condensers of the heat exchanger type, through which incoming charge was preheated by products leaving the towers. The remarkable thing about this installation is its close resemblance to the principles employed in present day practice.

If the shift over from shell stills to continuous pipestill operation marked a turning point for the petroleum industry, then the first turn-key refinery ordered, was another milestone in the progress of Power Specialty Company. A Canadian refiner ordered, in 1925, a plant complete in every detail on a single contract with undivided responsibility. Contracts of this type followed from other refining companies. Subsidiaries of Power Specialty Company were operated in Great Britain, Canada and later in France. The "closed door" era of petroleum refining technology had passed.

The Railway Petroleum Company ordered a topping plant, including three heaters and four towers, which was erected at Comodoro Rivadavia, Argentina, for the topping of crude and production of a satisfactory railway fuel. The railway engineers were greatly impressed with the quality of design and workmanship, for in spite of the fact that no superintendent of erection accompanied the equipment, every piece fitted perfectly, even to the extent that not a single bolt hole had to be redrilled. This definitely established the advantage of undivided responsibility and shortly after the completion of this plant the refinery ordered a fourth and duplicate unit to increase the capacity.

An expansion of importance was the addition of pulverized coal equipment to the company's products through the acquisition of the Aero Pulverizer Company. The Aero organization had been successfully firing solid fuels since 1896 and its experience provided a background unexcelled in the art. Pulverized petroleum coke, and pulverized coal fuels were introduced as a means of increasing the overall economy of refinery operation, including steam generators and oil heaters for various processes. The choice of fuels is still subject to fluctuations in market values and the demand for petroleum products. Balances may now be readily arrived at, however, since oil and gas are fired interchangeably, or simultaneously, with pulverized solid fuels through the same burners, developed specifically for refinery use.

Currently with these developments, the company had become intimately involved with the problems of fractionation and here, again, is an instance of pioneering—the introduction of single flash distillation systems, now accepted as standard practice everywhere. This accomplishment ranks high in the annals of refining, being diametrically opposed to batch distillation as practiced in tank stills.

The earlier heaters were used with vapor separators and dephlegmators capable only of indifferent fractionation. It soon became apparent that more complete separation of the various products requiring fractionation was needed to develop, to the full, the capabilities of the tubular heater or pipe still. By this time fractionating towers of the bubble cap type had been tried and found to be helpful. These had been used largely in connection with shell stills or as a series of fractionating towers with heaters between them, following much the same practice as used with shell stills arranged in a continuous battery. This required successive reheating of the charge with evident disadvantages.

It was felt that the system could be improved upon if the entire charge were heated to a temperature necessary to evaporate the highest boiling fraction and the combined vapors then discharged into the

flash chamber section, near the bottom, of a single tower where, following a single heating operation, the charge would be flashed and the vapors fractionally condensed. The lightest product would be taken as an overhead vapor stream to end point specifications and the intermediate boiling range fractions would be withdrawn from intermediate points on the side of the tower, later to become known as side streams. Despite the fact that this processing arrangement had many evident advantages, the single flash plan, as it was called, encountered criticism and skepticism.

Again a situation had arisen presenting a logical improvement in refining technique; Power Specialty felt that it had the knowledge and background to design a plant to operate on this system; but the refiners were skeptical. Not until the company offered guarantees under which it agreed to remove the equipment and refund the purchase price if expectations were not realized, was it possible to put into commercial operation a plant based on the advanced system of single flash fractionation. Under these conditions a refiner in the mid-west agreed, in 1924, to have such a plant built.

The purpose was to process 6,000 bbl. of crude down to asphalt bottoms producing gasoline overhead and heavy naphtha, kerosene, gas oil, light and heavy lube oil side streams. The unit was sufficiently flexible to process as an alternate operation 10,000 bbl. per day down to long residue bottoms, taking gasoline overhead and kerosene and gas oil as side streams. The plant was designed and constructed throughout by company engineers from charging pump to receiving house manifolds, then put into operation. This was the first complete still even remotely approaching this size and completeness of separation of products ever undertaken entirely by a company specializing in the design and manufacture of petroleum refining equipment.

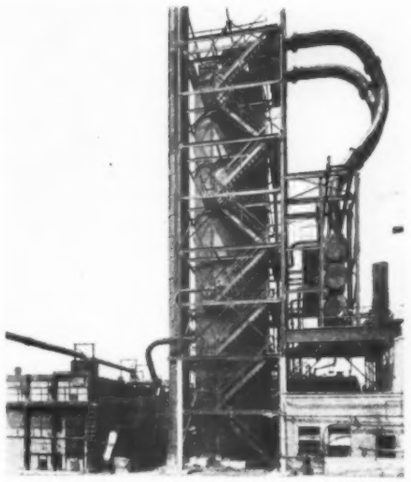
The installation was notably successful and made use of a single fractionating tower 10 ft. 6 in. in diameter and 120 ft. high. The size of this tower was so unusual that it aroused considerable skepticism on the part of refinery engineers. The compactness, flexibility and ease of handling that characterized this unit afforded an interesting comparison in the same refinery, with an installation of nearly the same throughput, consisting of many smaller towers arranged in series to operate continuously. This older unit was limited to the alternate operation and had little flexibility. Conversely the flexibility of the new equipment and its ability to handle the two different operations effectively, were outstanding advantages. The effectiveness of the new arrangement was so evident that the initial installation was quickly followed by others and the single tower, or single flash system of distillation, became universal practice. Thus an advance in refinery operation became available to the whole oil industry through the willingness of an engineering company to assume full responsibility for its performance.

The first tower included a large flash section, located above the bottom stripping section, as is done in modern units. Fractionation was obtained by a system of bubble trays equipped with adjustable caps which made it possible to get effective fractionation over the entire tray area. Side streams, as in the modern towers, were controlled by weir type valves introduced by the company. Adjustment of these valves controlled the percentage of reflux flowing through the towers and effected positive control of product characteristics. For instance, in distillation streams the end point would be raised with a reduction of reflux and lowered by an increase. Viscosity was raised with a decrease of reflux and lowered with an increase. The gravity was raised by increasing the reflux, and lowered by reducing it. Most important, however, is the fact that the characteristics of all fractions remained unchanged regardless of rate of charge if top and bottom tower temperatures were held constant.

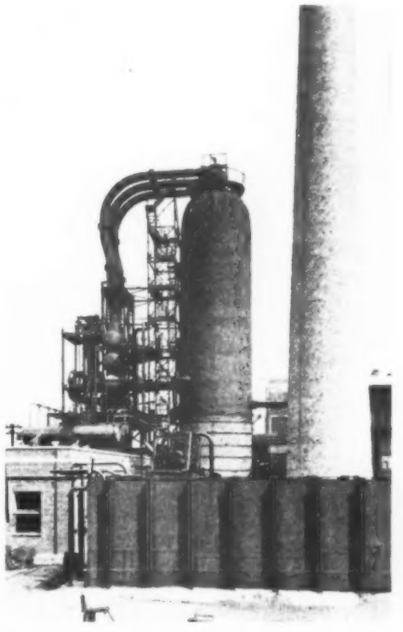
Power Specialty Company it will be observed had made an intensive study of adding heat to fluids.

Leading a separate corporate existence was another organization, Wheeler Condenser and Engineering Company, whose main purpose in life appeared to be the undoing of all the work that Power Specialty Company was so successfully performing. Wheeler Condenser specialized in cooling the very fluids that Power Specialty Company was heating. Certainly a combination of the two would result in complete annihilation, the cancellation of the efforts of one group against those of the other. Management of the two companies, however, was not deterred and chanced these dire results to form in 1927, a thoroughly logical combination of engineering experience. This permitted interchange of information that made it possible for the newly formed Foster Wheeler Corporation to offer coordination of heating and cooling knowledge essential to effective refinery design and construction. The name "Foster" was derived from the founder of Power Specialty Company and had been used as the trade name for its superheaters, economizers, and other products.

Few refineries have an unlimited supply of cool, inexpensive fresh water, and for this reason the use of cooling towers by refineries is general and exceedingly important. Processes which depend upon a

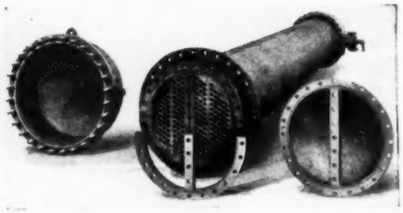


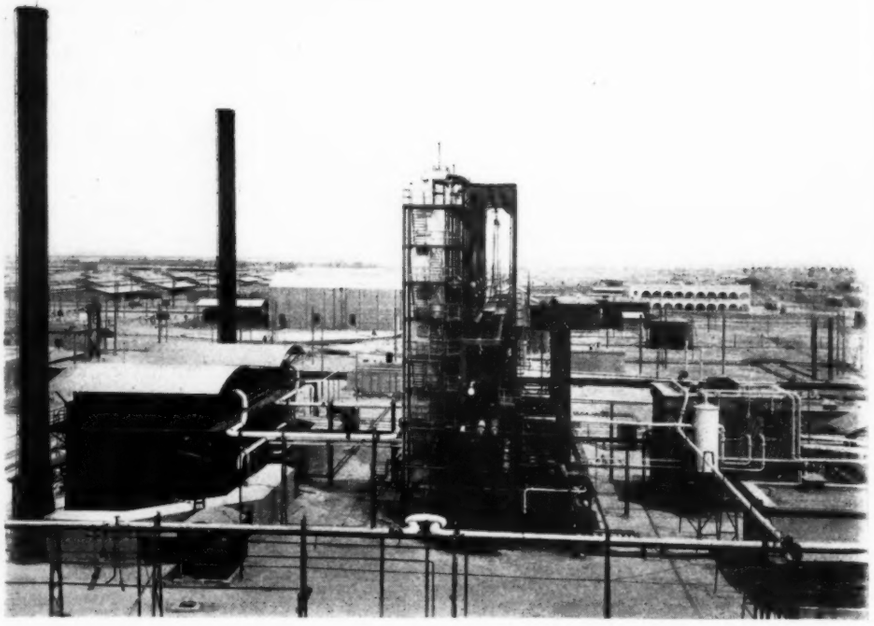
Single flash vacuum still processing reduced crude received from shell stills at the Parkersburg, W. Va., refinery of Standard Oil Co. of N. J.



General view of large vacuum pipe still installed at the Bayonne, N. J., plant of Standard Oil Co. of N. J. in 1928. This was the largest fractionating tower built up to that time, being 18 ft. 6 in. in diameter.

definite dissipation of heat for satisfactory completion may be seriously curtailed during hot, calm weather and drought. More than thirty years devoted to building cooling towers had included much refinery application. The largest louvre type tower in the world was erected for a Texas refinery a few years ago and was followed shortly by a second, undoubtedly the largest application of its kind ever made by a single manufacturer. Each tower is 999 ft. long by 54 ft. high; placed end to end, they form a virtually unbroken cooling device 2,000





Top, longitudinally baffled heat exchanger first used at Paulsboro and now standard for cooling light fractions close to water temperature. Right, two of seven similar single flash distillation units in Iran. Each of the two units has a capacity of 14,500 bbls. per day.

ft. long, having a capacity of 110,000,000 gal. per day—cooled from 115 deg. F. to 85 deg. F. California redwood was used exclusively in their construction and 64 freight cars were required to carry the lumber for the two towers; this would make a train twice the length of the towers, or about four-fifths of a mile long.

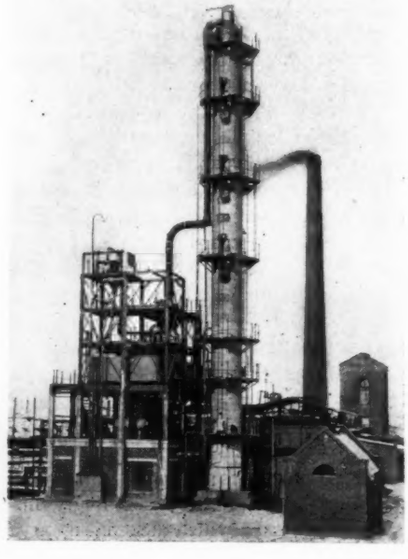
The capacity of atmospheric cooling towers depends so greatly upon velocity of wind and its direction that Foster Wheeler began developing mechanical draft towers early in the art and has pioneered in such work even to the extent of developing its own fans based upon tests run on them in the wind tunnel of the United States Government at Washington. These fans are now constructed of Dowmetal—a magnesium alloy introducted by the Dow Chemical Company—having approximately 50 percent greater strength than aluminum and 30 percent less weight. This permits mounting large fans directly upon the shafts of small gear motors, thereby eliminating expensive drives and starting equipment.

The fans have proved more efficient than those formerly used and are arranged with blades adjustable for three pitch positions: normal, summer and winter. By taking advantage of this flexibility and setting the blades for the duty required, a power saving of 40 percent may be effected. Capacity of mechanical draft towers may be calculated for any extreme weather condition in advance, and reduction in plant production due to insufficient cooling thus definitely eliminated.

Cooling towers have been supplied to refineries from British Columbia to Burma. Largest refinery order for forced draft cooling equipment was placed in September this year and includes two towers with a total of 30 cooling tower cells, each fitted with a 12 ft. diameter axial flow fan.

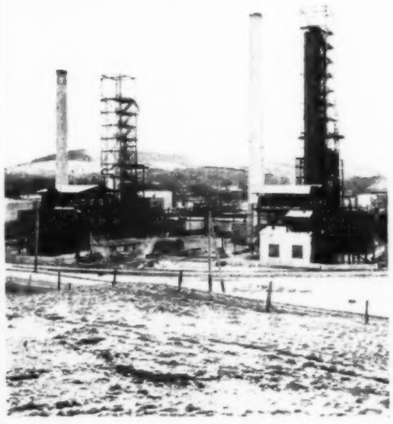
An activity worthy of mention is the design and construction of an experimental distillation unit which was presented to the University of Oklahoma for use with courses in petroleum engineering. This provided an excellent means of carrying on experimental work without the necessity of curtailing production or upsetting schedules in refineries. The capacity is 200 bbl. per day, which may be run to asphalt bottoms, and although only an experimental unit, carload quantities of crude oil, and other charging stocks, may be run to give data closely approximating results that would be obtained under commercial refining conditions.

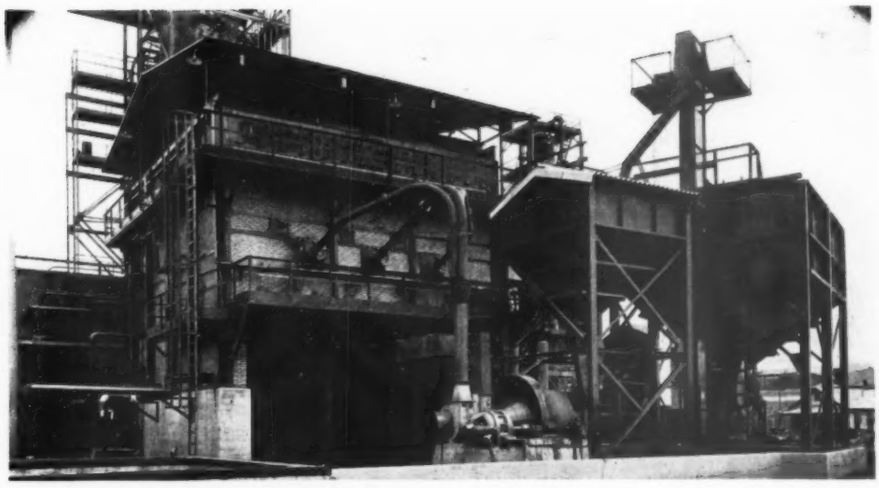
At this same time an important addition was made to commercial distillation in the development of vacuum fractionation, and its combination with atmospheric fractionation, to provide two-stage units of the single flash type. First installation of this kind brought the art of petroleum distilling close to its present day level, so far as broad principles are concerned. The initial unit was designed to charge Pennsylvania crude to the first stage, including a tubular heater and tower operating at atmospheric pressure, in which gasoline vapors were removed from the top of the tower with side streams of liquid kerosene, light gas oil, and mineral seal oil. Reduced crude was then passed to the second stage, which also consisted of a tubular heater and tower, operating under a vacuum. The hot bottoms from the atmospheric tower were further heated and released into the flash chamber at the bottom of the vacuum tower. The result was heavy gas-oil vapors overhead and liquid side streams of light and heavy wax distillates. Bottom stream from the vacuum tower was high grade cylinder stock running from 16 per cent to 25 per cent of the total crude charge. Capacity of the unit was 7,800 bbl. per day.



Distillation unit of Gazy Ziemne at Lwow, Poland, with a capacity of 800 bbl. per day.

The outstanding success of this two-stage, single-flash fractionating combination was due in a large measure to the application of effective vapor condensers that were first used in this pioneering unit. The principles employed were those that had been proved in steam plant service for many years and included what is known as the drip-type principle, using no baffles that might cause dead spots and increase the pressure drop between vacuum pump and fractionating tower. Because of the importance of vacuum operation, design of the vapor condensers is of prime consideration and must be such as to impose minimum pressure drop in order that the full vacuum produced by





Left, two single flash distillation units at the Wellsville, N. Y., plant of the Sinclair Refining Co. At the right is the tallest bubble tower in the world. Right, one of three Foster Wheeler pulverizer fuel fired tubular furnaces at Wellsville, N. Y. In the margin are shown two views of the cans in which products are distributed in Poland, the quality of the oil indicated by a picture of the Foster Wheeler unit in which the products are made.

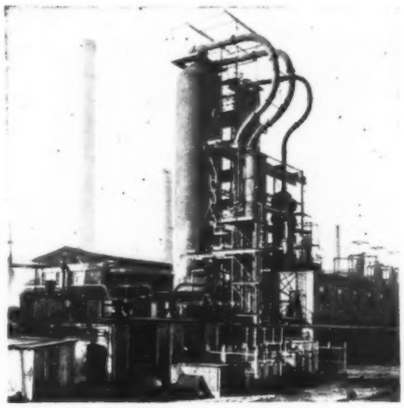
pumps and condensation may be carried through to the flash section of the tower. Construction as developed incorporated large rectangular openings in the shell of the exchanger and an arrangement of the cooling surface that still stands as the basic method for use with vacuum units. The fact that this two-stage installation was made without precedent or commercial experience upon which to base the vacuum stage design, and that the guarantees were extremely rigid, is an excellent indication of the value of background in pioneering.

Startling performance was introduced to refiners at this point. Ample margins of safety had been employed in designing the unit, due to lack of any previous experience in such vacuum work, but even so a profound impression was created when the still exceeded its guarantee by a substantial margin, on a lower fuel consumption than anticipated, and with an unexpectedly low consumption of stripping steam. Still more important from the refiner's point of view was the quality and high yield of valuable lube fractions. The shell stills had been shut down by this refiner with trepidation and skepticism was rife regarding the ability of a single unit to accomplish the promised results. It is a matter of record that the shell stills were never again started up. The saving in labor was 70 percent and the fuel efficiency was increased from 30 percent in the shell stills to 75 percent in the new unit. Maintenance costs were greatly reduced and rerunning of products eliminated since specifications were met directly in processing operations. The total result was that the plant paid for itself in less than six months after being placed in service.

The breadth of application of vacuum distillation was indicated by the use of two large single flash units in conjunction with existing batteries of shell stills equipped with modern accessories. These were the first large vacuum fractionating units to process reduced crude after it had been topped in shell stills. Reduced crude from the shell stills was heated in tubular furnaces to about 800 deg. and discharged into the vacuum tower where gas oil vapors, three lube oil side streams and heavy asphalt bottoms were recovered.

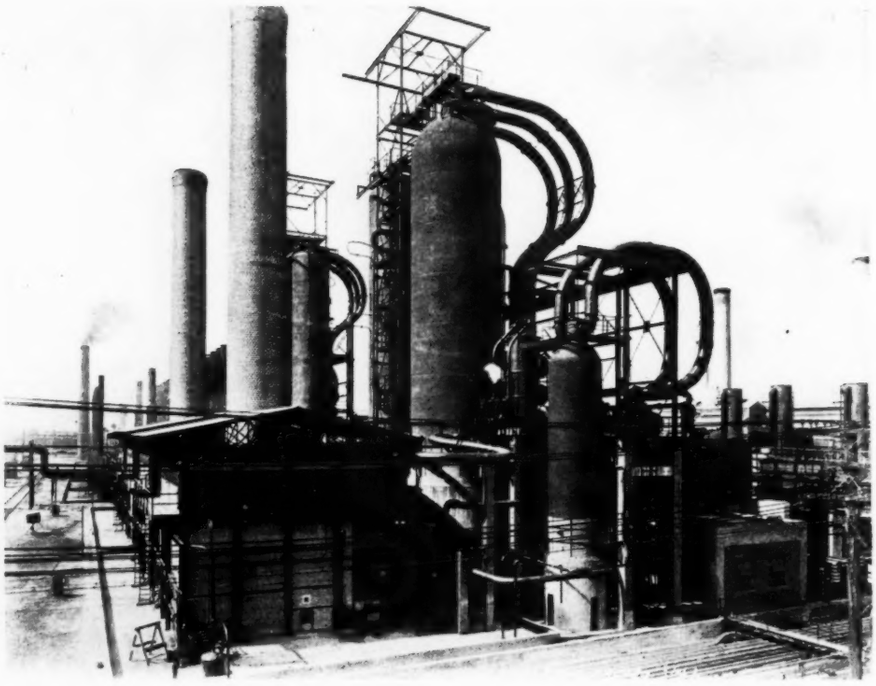
During this period the Corporation's engineers made a notable advance in the design and installation of true counter-current flow heat exchangers of tight baffle construction. Previous to this time all attempts to make longitudinal baffles tight had proved unsatisfactory. In the new heat exchangers designed for cooling to temperatures closely approaching the water temperature, the longitudinal baffles were welded to the shell throughout their entire length, thus assuring true counter-current flow of fluids without short circuiting during the entire life of the equipment. The advantage of this construction was so obvious that it has become standard practice for all heat exchangers working on close temperature differences.

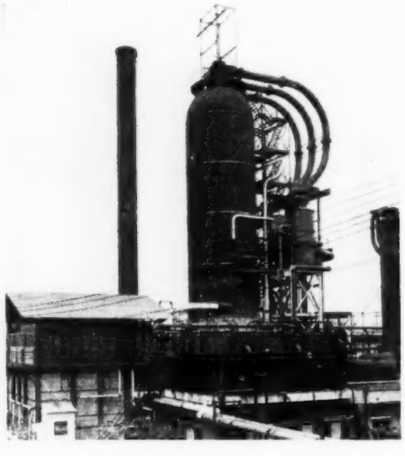
Two stage distillation unit, designed for maximum yield high viscosity lubes from high grade naphthenic crude, erected in 1929.



Extension of activity to the oil refining centers of the world was making material headway and the installation of two large atmospheric fractionating units was made for Anglo Iranian at Abadan. A considerable number of tubular heaters had already been furnished to the Abadan refinery, but these initial single flash units were designed for 12,500 bbl. per day each to recover gasoline, kerosene and fuel oil residuum in a single operation. Before the first two units could be completed and put into service an additional order was placed for two more duplicates. Many subsequent refining units have been provided for Iran, Czechoslovakia, England, Germany, Iraq, Italy and Hungary. Japan, Poland, Russia and Wales are other countries to which single-stage atmospheric, and single-stage vacuum units were supplied In Russia fractionating equipment was installed with a total through put of approximately 100,000 bbl. per day. Construction work was carried out under the direction of American engineers.

To understand the position of Foster Wheeler at this time it is necessary to remember that plants of their design and construction were rapidly being spread a'l over the world. Some curious reactions have resulted. In Poland, the Gazy Ziemne organization was so pleased with the performance of their equipment that they decorated the cans in which the products were sold with a picture of the units and stated that the quality was so high because Foster Wheeler apparatus was used in its production! More recently, there has been received from this





Above, two three-stage distillation units erected in 1929 for the Gulf Refining Co. at Port Arthur, Texas. Left, the first Foster Wheeler gasoline absorption and stabilizing plant installed complete in 1929 at Kettleman Hills, California. Below, large reduced crude single flash vacuum unit erected in 1930 for the Tidewater Oil Co. at Bayonne, N. J.

company a letter of testimonial expressing appreciation of the fact that the original installation, now several years old, has been increased in capacity and improved in performance by making changes suggested by engineers of the English company. The form of the appreciation was very straightforward and pleasing. It is not generally known in this country but the synonym for pipe still installations in Poland is "Foster Wheeler." This may seem suprising but it is the actual and literal fact. In Germany, by contrast, 18 units for various duties have been installed during the 'ast four years chiefly in connection with the treatment of products obtained in the hydrogenation of coal tar. They include distilling, stabilizing and gasoline treating equipments with one repeat order. No information can be secured concerning the details of these plants, so far as their operation is concerned. Thirteen of them were ordered during the last two years and their operation has been eminently successful.

Tallest tower ever built was erected in 1929 to handle Pennsylvania crude and produce continuously eight side streams, in addition to overhead gasoline and cylinder stock bottoms. The tower is 153 ft. high and has been in successful operation ever since. The furnace feeding this tower is an example of the versatility offered by the engineering departments of the Corporation and is fired by a Foster Wheeler pulverized coal system.

First successful operation to produce maximum yield of overhead cylinder stock from premium grade Mid-Continent crude in a single operation was accomplished through the installation of a two-stage distillation unit of 7,500 bbl. per day capacity installed at Paulsboro, N. J., for Socony-Vacuum. Cylinder stock was taken as a side stream from the vacuum tower leaving a small percentage of asphalt bottoms. Cylinder stock cuts ran from 13 to 18 percent and the asphalt bottoms from four to five percent, depending upon the character of the crude charged and side stream specifications.

First three-stage distilling units produced by the organization were constructed in 1929 at Port Arthur for crude distillation. They were the largest then built and processed 15,000 bbl. of crude per day each to low penetration asphalt bottoms. Arrangement includes a high vacuum, third stage, which is added for the overhead distillation of heavy cylinder stock from the usual two stage effect. This provides a smaller percentage of bottoms with higher yield of overhead cylinder stock.

Trucks rumbling night and day over a roadless waste in central California announced the entrance of Foster Wheeler into gasoline absorption work. Fifty days after signing a contract with Doheny interests the corporation was to complete a unit to recover gasoline from 100,000,000 cu. ft. per day of natural gas. The recovery and stabilizing plant including steam generators, cooling tower, storage tanks and shipping facilities went bouncing over the mountain ridge in heavy trucks 200 miles from Los Angeles. Two days before the deadline the plant was completed and shortly achieved the distinction of providing the highest percentage recovery in the Kettleman Hills field. Notwithstanding the speed that attended the erection of this remote plant, Foster Wheeler has successfully applied a novel feature consisting of pumps driven by turbines operating on high pressure natural gas—preheated to prevent accumulation of frost from stopping the turbines.

Great size, in the abstract, is sufficient to compel attention of engineer or layman, and for that reason the vacuum distilling unit of an Eastern refiner to handle 9,250 bbl. of reduced crude per day is interesting. The tower is 21 ft. in diameter and 111 ft. high—largest built at that time (1930) on the basis of volume or throughput. Its duty is to produce five specification fractions from a charge which had been topped in shell stills. Products are gas oil, pressable wax distillate, heavy wax distillate, overhead cylinder stock and heavy asphalt bottoms.

As may well be understood from references to construction work at home and abroad, considerable experience was gained in that involved phase of constructing complete units. One of the outstanding accom-

plishments was the design, fabrication and installation of a group of four complete two-stage distillation units having a regular daily throughput of 50,000 bbl. of crude yielding nine products overhead, including cylinder stock. The eight towers with their eight heaters and four large stacks were erected simultaneously. This is an operation of no mean proportions and its satisfactory completion involved most valuable experience in large scale work in the field.

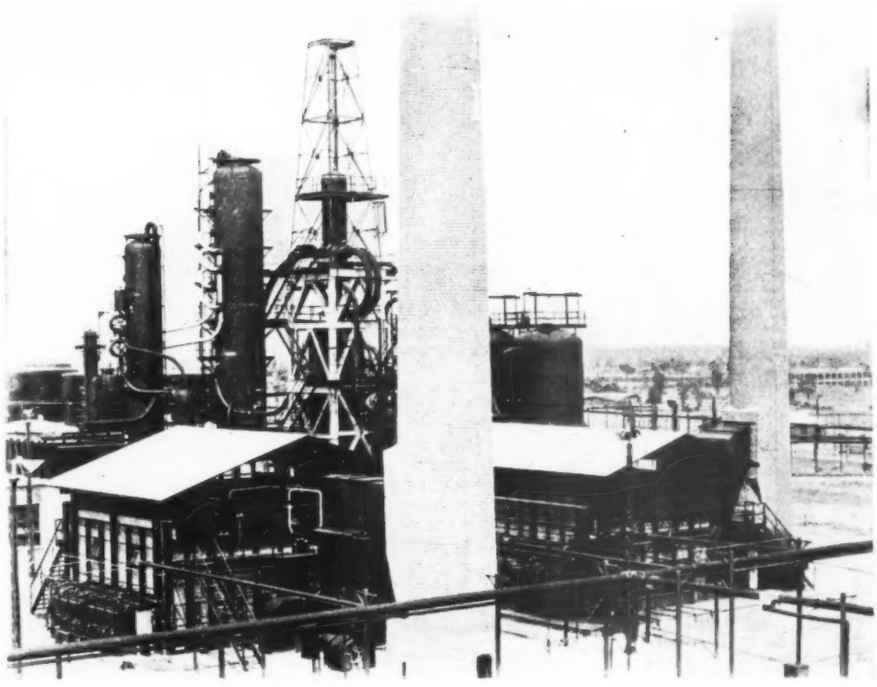
Solving a processing problem for a new crude is exemplified in the handling of East Texas crude that became available about the time these four units were completed. It had previously been considered difficult to obtain pressable and sweatable wax distillate from East Texas crude. Distillation specifications of the wax distillate were varied until proper characteristics for this product from an entirely new crude were determined to assure a maximum yield of easily pressable wax distillate, providing a readily sweatable slack wax. As soon as these specifications had been determined, proper regulations of the controls on the special side stream devices assured continuous and uniform production. This development stressed the importance of a high degree of fractionation in the production of suitable wax distillate.

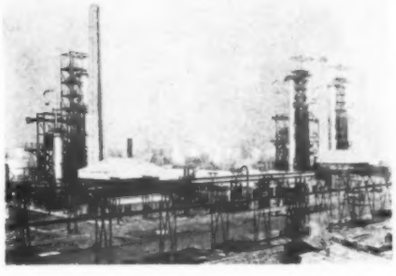
Another American refiner installed, in three different plants, two-stage, atmospheric and vacuum distillation units designed to rerun treated cracked gasoline under special low temperature conditions. The three units have a combined capacity of 20,000 bbl. of treated cracked gasoline per day which is fractionated under closely controlled temperatures. This produces a color and gum stable gasoline maintaining its high anti-knock rating. These units were among the first of their kind, but have been followed by several others of the same design and several of modified design to produce similar results.

In France a complete refinery was constructed including two, two-stage, atmospheric-vacuum, all purpose crude distilling units and two single-stage rerun distilling units, together with a complete steam power plant. The capacities of the crude units are 5,000 bbl. per day each, although the units were originally designed to process approximately 4,000 bbl. per day of Ranger or Coastal crude, recovering as many as eleven different fractionated products simultaneously from each unit. Actually, much of the charging stock has consisted of Iraq crude but as the units are designed for such a wide range—from Ranger on the paraffinic side to Coastal on the naphthenic side—almost any other crude may be processed to specifications.

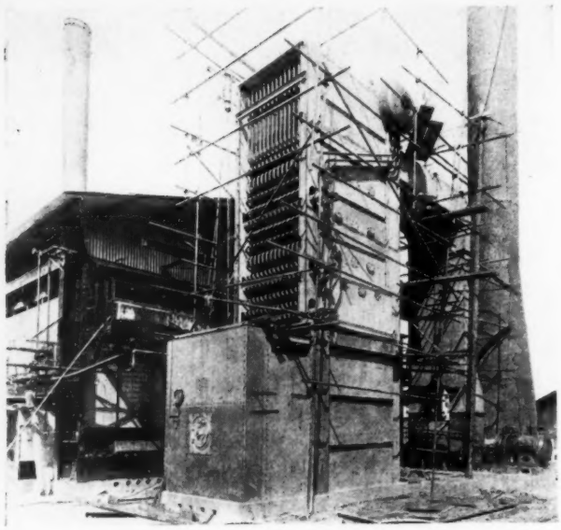
At the same time three other French refineries installed single flash distillation units and another refinery installed the first crude stabilizing unit. The stabilizing plant was designed to handle 20,000 bbl. of crude per day which was first settled and then predistilled to give a stable and non-corrosive product free from hydrogen sulphide odors. The predistillation was accomplished at temperatures low enough to prevent corrosion. Overhead product from the prestabilizer was delivered to a combination recovery and stabilizer unit. The lightest gases were delivered to the refinery fuel lines and heavier gases were compressed for sale in bottled form. Scrubbed and stabilized gasoline was delivered to storage tanks. The same refinery also has a two-stage pressure distillate rerun unit in which raw product was heated first in vapor heat exchangers and then in film type evaporators for each stage of the process. Heating medium was recycle stock from the cracking plant.

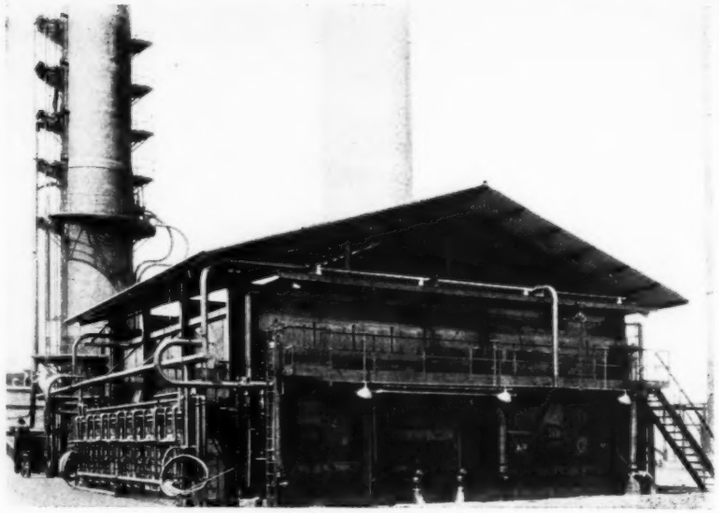
With the great progress made in cracking and the increase in size of units, demand for cracking furnaces of unprecedented dimensions involved new studies and arrangements. Two furnaces were installed in the East Montreal refinery of the Shell of Canada, using the Dubbs process. One heater had a capacity of 41,000,000 B.t.u. per hour and the other furnace had a capacity of 36,000,000 B.t.u. per hour. This was a large installation at the time for a single cracking unit and provided for selective cracking which was then a novelty. Cracking light oil in one furnace and heavy oil in the other permitted a selectivity of the temperature and pressure conditions ideal to each fraction of the same charging stock as never before realized in a commercial plant. The method employed to increase the efficiency of the heaters, since the temperature of the entering oil was too





Above, two heaters, one a selective cracking unit in operation at the East Montreal Refinery of the Shell Oil Co., Ltd. Right, Port Jerome, France, refinery showing four Foster Wheeler distillation units. Below, Foster Wheeler laboratory building at Carteret, N. J.





Left, one of three cracking heaters being installed in Trinidad during 1936. Right, cracking furnace for the absorption of 85,000,000 B.t.u. per hour installed at the Shell Oil Company's East Chicago refinery.

high to reduce flue gases sufficiently, was the application of air heaters to preheat the air for combustion. Many such air heater applications have been made and this may be considered the standard method, although it is not the only one.

In line with the conservation of heat and corresponding reduction in operating costs, any direct fired units—such as cracking heaters—having high inlet temperatures and, therefore, no means of reducing the temperature of outgoing gases to a satisfactory extent, present a problem in heat recovery that involves savings of appreciable magnitude. Application of air preheaters to cracking heaters reduces stack temperature by preheating the air for combustion and renders the overall operation of the unit more efficient. Another method of recovering heat and one which has met with greater approval in several instances, is application of waste heat boilers, which achieve a substantial and very desirable saving. Through the use of boiler tubes covered with extended surface, cast iron rings, an effective means of absorbing heat from low temperature gases is provided.

This installation clearly indicates the simplicity of combining a waste heat boiler with a cracking heater. In this particular instance steam is generated at 150 lb. pressure, the quantity being 15,000 lb. per hour. The addition of two cracking units to this South American refinery meant an increase in steam load, whereas there was no surplus capacity in the existing steam generating units. Instead of adding new boilers to the refinery, and air heaters for the cracking furnaces, waste heat boilers served the triple function of saving an appreciable part of the cost of new, direct fired boilers; providing the additional steam necessary in process work; and effecting necessary heat recovery in order that maximum return might be secured from the cost of fuel used in the cracking heaters.

The limit in size of cracking heaters had not been reached and a large one was furnished for a southwestern refinery. The furnace is so huge that the radiant section and the convection section are practically in separate buildings. The combustion chamber is 32 ft. wide, 68 ft. long and 24 ft. high. It is fired with 16 large oil burners placed along one side, truly an inferno of awesome proportions. The roof of the combustion chamber is lined with four rows of radiant heat absorbing elements to provide final heating and soaking of the oil. This unit was so much larger than any ever built that refinery engineers in general believed that it would never be exceeded in size. Within one year, however, a still larger heater was put into service.

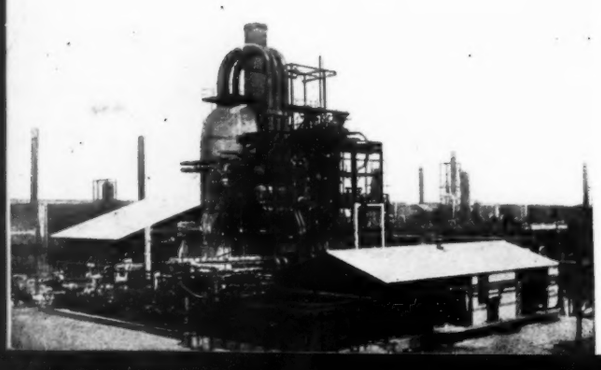
In 1933 Foster Wheeler built a cracking heater in a Mid-Western refinery for the reforming of 10,500 bbl. of gasoline per day. This heater was designed for a heat absorption of 85,000,000 B.t.u. per hour and was the first to include three distinct sections arranged for intermediate coil temperature control. The heater consists of three parts arranged in a single setting including two combustion chambers with a convection or preheating section placed between them. One combustion chamber serves as the cracking heater and the other as a soaking coil, each being operated to give desired temperature control independent of the other furnace. Both furnaces are practically surrounded by radiant heat absorbing elements.

Raw charge after being preheated in exchangers is pumped through the convection tube bank and thence through successive rows of elements in the cracking coil. The cracking coil is heated by 15 combination gas and oil burners located in the side wall of the furnace. Charge then flows through the soaking coil which is heated by 12 combination oil and gas burners in the side wall of that furnace. The products of combustion unite above the convection tube bank and then flow down through the convection section of the heater to the stack. No air heaters are necessary to provide high efficiency in this reforming heater because the charge enters the convection tube bank at a comparatively low temperature. Operation of this heater has been so satisfactory, due to the intermediate coil temperature control, that this design is now standard for large reforming heaters. Since it was installed, two heaters of 96,000,000 B.t.u. capacity, two of 32,000,000 B.t.u. capacity, and one of 108,000,000 B.t.u. capacity were built for the same organization in five different refineries.

The largest crude stabilizing project ever attempted was carried out in 1935 when the Iraq Petroleum Company authorized the installation of a plant in the Mesopotamian desert capable of charging 135,000 bbl. per day. The installation includes three, two-stage units of 45,000 bbl. capacity each, the purpose of which is to remove hydrogen sulphide before the crude enters the famous Iraq pipeline, which extends some 600 miles to the Mediterranean seaboard. Light gasoline fractions are removed, stabilized, treated and pumped back into the crude. Dry gases recovered from the process are more than sufficient to meet all fuel requirements of the plant. This project is at an inaccessible point, is under strict control of European authorities and rigid regulations apply to the refinery compound. It has to be self-supporting as to facilities and the water supply, heat, light and power are all part of the undertaking.

While making mention of the Iraq pipeline, it may be pertinent to point out that the pumping stations are equipped with

Large 35,000 bbl. per day atmospheric and vacuum unit located at the Lago Oil and Transport Company's Aruba Refinery.



Diesel engines. There is no water supply for most of these stations and, therefore, cooling water for the engine jackets must be preserved with utmost care. Cooling towers would not be practical due to the high percentage of water loss and a novel arrangement of heat exchangers was substituted. Oil going through the pipeline is relatively cool and sufficient oil is passed through the heat exchangers to absorb heat from water circulated through the engine jackets. Addition of this heat to oil in the pipeline is insufficient to create any marked effect but has a tendency to reduce viscosity and, therefore, facilitate pumping. The accompanying pictures of the Iraq plant give some idea of the installation but due to this being very much in the line of an outpost, problems are far more complicated than the ordinary refiner is accustomed to.

Four years ago the Administracion Nacional de Combustibles, Alcohol y Portland of Uruguay, decided to build a complete refinery starting from scratch—literally without any foundation, since neither the refinery site nor an experienced refinery personnel existed in Uruguay at that time. The Republic contains no developed oil deposits and, therefore, experienced oil men were not available.

A technical staff was organized by selecting a number of brilliant young engineers and sending them to study refinery practice in neighboring countries and the United States, including design, fabrication, construction and operation. Site was constructed on Montivideo Bay by taking advantage of the dredging of channels. Bulkheads were installed adjacent to the A.N.-C.A.P. storage depot and a sand fill made to provide a clear, level site with deep water dock to accommodate ocean going tankers. Piling was driven to solid rock to carry equipment foundations. The preliminary studies resulted in arranging an acreage large enough to accommodate extensive future expansion, and the selection of Foster Wheeler to carry out the complete program.

A 4,000 bbl. per day refinery was the first objective and it was to be essentially self-contained and independent, including atmospheric crude distillation, Dubbs selective cracking unit, cracked gasoline treating plant and gas absorption. Gasoline stabilization, continuous gasoline sweetening and kerosene and special naphtha treating had also to be constructed. Auxiliary equipment consisted of a steam power station, pumping station, central fire defense station, sewers and drainage. Concrete roadways connected offices and laboratory, warehouses, shops and dock facilities. A large tank farm was built adjacent to the refinery.

The designs and materials originated in the United States, England and on the Continent. The divergence in country of origin was due largely to the availability of exchange, trade treaties, and comparative cost levels for various classes of materials and equipment. Unit responsibility afforded a coordination of engineering design and construction under which it was possible to start operating several test runs immediately after starting up.

Crude specified was Peruvian or Ecuadorian and, therefore, a wide range of flexibility was essential. In regular service the plant has processed more than 5,000 bbl. per day, yielding high quality products including: light gasoline, high octane cracked automobile gasoline, specialty naphtha, mineral turpentine and kerosene as well as Diesel oil, gas oil and bunker "C" fuel oil.

In particular this refinery was designed for economy, ability to handle any type of crude, safety and with all due recognition to appearance. It has been laid out with provision for doubling or tripling capacity, and for the addition of a solvent refining, dewaxing and treating plant to produce high quality lubricants. Its present condition is notable for after months of operation, a visitor would not be conscious that the plant is in operation. There is not the sign of a leak, spilled oil or overheating anywhere.

An interesting example of the present trend in the design of fractionating equipment is a combination atmospheric and vacuum distillation plant charging 20,000 bbl. per day of Panhandle crude. This plant recovers a 225 deg. F. endpoint light naphtha and in addition five cuts under substantially atmospheric pressure and five more cuts under vacuum.

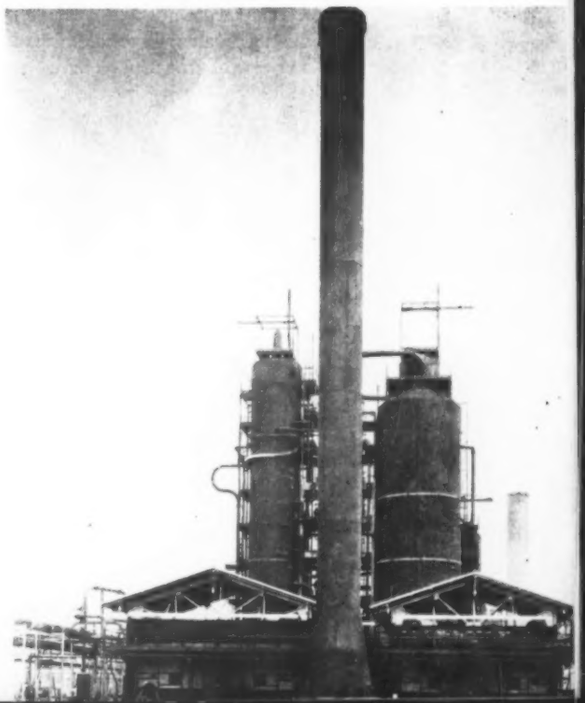
Because of the production of very light naphtha fraction, a prefractionating column operating at 35 lb. absolute pressure was selected to supplement the usual single flash atmospheric column in order to permit more effective recovery of heat by heat exchange.

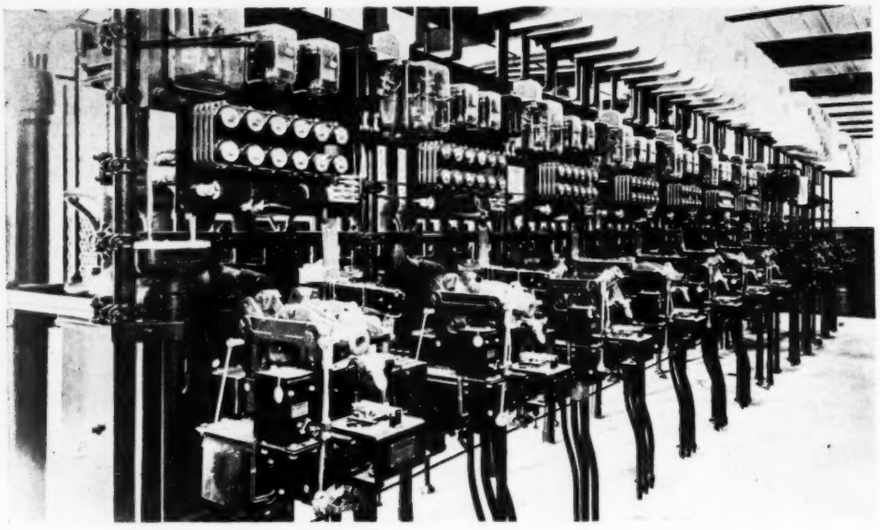
The prefractionating column also serves to dehydrate crude oil at a temperature of approximately 275 deg. F., making it possible to heat flashed crude in subsequent stages to any desired temperature without deposition of salts within heat exchangers or furnace tubes. It has been possible to operate for 90-day periods with salt concentration running as high as 200 lb. per 1,000 bbl. of crude. Sulphur content of the crude oil averages 0.7 per cent and this, together with the high salt content of the crude, results in generation of considerable quantities of hydrogen sulphide and hydrochloric vapor within the atmospheric column. Corrosion from this source has been held at a minimum by the use of Cupro nickel tubes in the vapor condensing system, lining of water separator tanks with concrete and use of ammonia as a neutralizing agent.

Airplane view of Ancap refinery at La Teja on Montevideo Bay, Uruguay.

An interesting feature in the design of this plant is complete elimination of the conventional condensing and heat exchange equipment for the vapors leaving the vacuum column. In large distillation units it is ordinarily necessary to use extremely large shell and tube equipment on these vapor streams in order to keep pressure drop on the vapor side of the equipment within a reasonable limit. The use of such large equipment is objectionable because of the maintenance difficulties involved. In this plant the oil vapors are completely condensed at the top of the vacuum column by means of a gas oil stream which is circulated through a shell and tube cooler and returned over the uppermost tray at the top of the vacuum column. Thus, only steam passes from the top of the vacuum column and enters directly into a barometric condenser. The practicability of this type of construction has been demonstrated by numerous Foster Wheeler vacuum distillation units now in operation, some of which have been on stream for periods as long as two years

Large crude-to-lube stock distillation unit in service at the Humble Oil Company's Baytown, Texas, refinery.





Interior of electric control room of world's largest catalytic polymerization plant. The large amount of electrical equipment needed gives a fair indication of the magnitude of this installation.

without any shutdown due to mechanical failure.

One of the largest distillation units in the world was designed for the fractionation of heavy South American crudes to special stocks for further processing. This equipment is a two-stage atmospheric vacuum unit of unusual proportions, the vacuum tower being 24 ft in diameter. Heavy crude is charged at the rate of 30,000 bbl. per day and naphtha and light gas oil are recovered in the atmospheric stage. In the vacuum stage 35 per cent of the crude charge or about 10,000 bbl. per day is drawn off in a single side stream. This is a special charging stock for another process and must be fractionated to close specifications. This special stock has an A.P.I. gravity of 18 deg. and a viscosity of 260 at 100 deg. F. Bottoms from the vacuum tower constitute a low penetration asphalt stream of 5 deg. A.P.I. gravity. This asphalt cut also runs about 35 per cent of the total charge or some 10,000 bbl. per day.

One of the most important developments now in the midst of rapid advancement in petroleum refining is the art of commercial catalysis. Many desirable chemical reactions that were not available to the refining industry on a commercial basis, due to the slowness of reaction, have been made exceedingly effective by the use of a catalyst. Polymerization is prominent in this classification and a catalyst is used to augment the speed of reaction.

Previous to 1934 the use of a catalyst to polymerize gaseous hydrocarbons to produce compounds in the gasoline range was an interesting laboratory experiment or a research toy in a refinery. At that time Foster Wheeler cooperated in the design of and built the first commercial catalytic polymerization plant, thus dedicating another milestone in the annals of petroleum. The Universal Oil Products Company's low temperature, low pressure, non-selective catalytic polymerization process was used, a tubular furnace heating 125,000 cu. ft. of gas per hour for delivery to four reaction towers wherein polymerization was effected. The polymer gasoline produced was condensed and fractionated to proper vapor pressure in a stabilization tower whence it flows to storage.

The world's largest non-selective, catalytic, polymerization and gas processing plant was recently designed, fabricated, constructed, and placed in operation for one of the most progressive refiners in the industry. In addition to the polymerization unit proper the plant comprises specially designed processing equipment including gas absorber, polymerized gasoline debutanizer, depropanizer, rerun unit, catalyst reactivation system, cooling tower, furnaces and all auxiliary equipment.

Formerly the gas charged to this unit was used only as fuel and, therefore, in the realization statement for this installation, the cost of the raw charging stock is low. Now, however, it is processed in the non-selective catalytic polymerization unit, valuable constitutents removed, and the remainder released for fuel.

The plant was designed to process, daily, 27,000,000 cu. ft. of gas from the cracking units, including 84,000 gal. of liquid butane, with a recovery of 2,190 bbl. per day of stabilized, high octane, polymer blending gasoline and 2,450 bbls. of liquid butane. Gas is taken from the high pressure gas separators at the cracking units, at pressures varying from 180 to 250 bbl. per sq. in., compressed to 320 lb. per sq. in., then mixed with gas taken from the depropanizers at the cracking units and charged to the process furnace. The liquid butane is charged into the furnace at an intermediate point. Total pressure drop through the process furnace is only 25 lb. per sq. in.

From the process furnace the charge is sent to catalyst chambers which are designed for the proper contact time and low pressure drop.

The effluent from the catalyst chambers passes through heat exchangers and coolers and then is passed into the lower section of the absorber tower, which operates at about 225 lb. per sq. in. Butanes and heavier constituents are removed from the gas in the absorber and the remaining gas is passed from the top of the absorber into a dry drum and then released to the refinery fuel gas system at a pressure of about 50 lb. per sq. in. Liquid from the absorber, which consists in part of rich absorber oil and in part of condensate obtained directly from the effluent from the catalyst chambers, is passed to a feed surge drum of 700 bbl. capacity and is then charged from this drum to the depropanizer unit. Charge to the depropanizer is pumped through several heat exchangers, thus utilizing heat that would otherwise be wasted. The depropanizer is operated at about 350 lb. per sq. in. pressure. Overhead vapors pass through a condenser and into a reflux separator where the gas, consisting of propane and lighter hydrocarbons, is rejected into the refinery fuel gas system.

The bottoms from the depropanizer are sent to a debutanizer where essentially all butanes are taken overhead and the bottoms recycled back as lean oil for the absorber. A side stream from the debutanizer, having the desired vapor pressure, is charged directly to the rerun unit. Overhead from this rerun tower is high octane polymer gasoline. From the rerun unit it is pumped through a sweetening plant to final storage.

Reboilers in the polymerization plant usually are supplied with heat obtained from one of the cracking units. Provision is made, however, for obtaining heat from the process furnace by circulating gas oil through the process furnace and reboilers during shutdown periods of the cracking unit.

A superheater furnace provides the dual service of producing flue gas and superheating the gas and air for reactivating the catalyst. The combustion chamber of this furnace operates under pressure with controlled combustion to regulate the free oxygen in the flue gas.

Part of the flue gas, after passing through the catalyst towers is scrubbed, cooled, and compressed, then scrubbed again and heated in the superheater furnace and recycled back to the catalyst bed during the reactivation period.

One of the principal points to be noted in this installation is its accessibility and rugged construction. Extreme care has also been taken to minimize corrosion.

With the tremendous increase in importance of petroleum derivatives for industrial and military use, those countries without

natural pretroleum resources have been hard put to protect themselves from a shortage. Italy, for example, has found it necessary to develop large storage for imported crude and to install such well known refineries as Aquila at Trieste, A.G.I.P. and the A.N.I.C. plants at Bari and Livorno. Since all of the crude is imported and since it may come from many different sources, great stress has been placed upon effecting the highest recovery of usable products. This in turn necessitates most effective coordination of the various refining processes and maximum flexibility in the operation of the units. It is obvious also that the products must include highest grades of motor fuel and lubricants for aeroplanes and other military motors.

The Aquila refinery, for example, has sufficient capacity to provide fully 50 per cent of the lubricating oils and 20 percent of the fuel oil and motor fuel demands of the country. Full capacity is between 800 and 1,000 tons of crude per day, depending upon its characteristics and the output of refined products should run between 300,000 and 350,000 tons annually. Under ordinary conditions, this refinery could supply a large range of derivatives for export, as well as domestic trade.

The A.N.I.C. plants are unusually complete in their processing departments. The capacity of each is between 700 tons of Rumanian crude and 900 tons of Albanian crude per day. These diametrically different crudes cover the full range of possibilities. The first process is one of prestabilization and it is followed by atmospheric distillation. Treatment includes the usual acid, caustic and doctor plants. Specifications are met in fractionating operations with maximum accuracy in order to minimize rerunning. Cracking units, hydrogenation and hydro-stabilizers are included in the exceptionally complete detailed processing department.

An outstanding contract of Foster Wheeler Corporation for the year 1937 consisted of the construction of six different refinery units or processes in a single refinery. All six of these units were erected simultaneously and included a complete selective cracking plant with heavy and light oil cracking furnaces; also a naphtha reforming unit with a specially designed reforming furnace and a gas plant using reboilers and heat exchangers with gas oil circulated through a furnace as heating medium.

A vacuum flashing process for cracking still residuum was installed using a specially designed furnace and a high vacuum tower.

Cooling towers and other heat transfer equipment required in conjunction with the additions to the refinery were also ordered.

Waste heat boilers were installed in connection with new cracking furnaces to generate steam from the flue gases of these furnaces.

A two-stage atmospheric-vacuum rerun unit was built for processing 6,000 bbl. of treated cracked gasoline per day; integral film type evaporator heat exchangers are used in this unit to transfer heat from steam at the lowest possible temperature with the greatest economy.

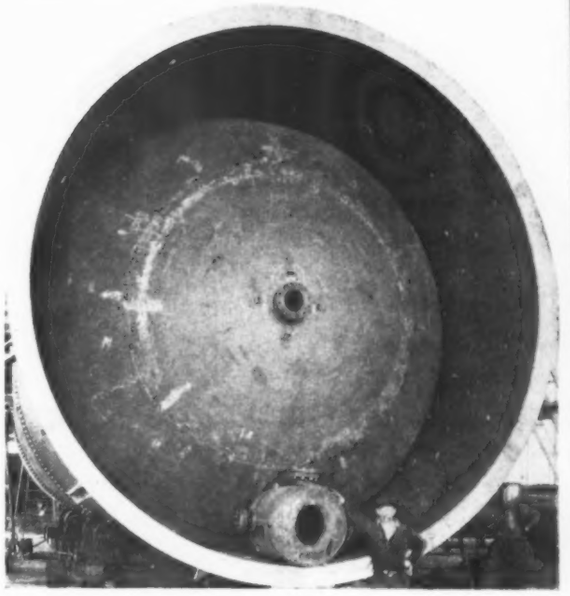
An iso-octane process licensed by Universal Oil Products Company designed to polymerize and hydrogenate about 1,000 bbl. per day of butane-butylene is included. The finished product is a valuable blending fluid used in the manufacture of highest quality aviation gasoline.

A furfural selective solvent treating plant licensed by The Texaco Development Company forms part of the refinery. This treating plant processes high grade lubricating oils and special Diesel engine oils.

An addition to the existing steam generating plant was designed and constructed including a new oil and gas fired boiler unit to supply 50,000 lbs. of steam per hour at a pressure of 475 lb. per sq. in. gauge, and a final steam temperature of 750 deg. F. The steam generating unit was complete with extended surface high pressure economizer designed for maximum efficiency and a combination radiant and convection superheater installed to give a constant final steam temperature regardless of rating.

The most interesting phase of the fabrication of the above work was the shipping of towers for the cracking units completely assembled. The towers were welded in the shops and carried as deck load aboard ship to the refinery harbor. At their destination they were rolled overboard and towed to the shore by small boats. This novel scheme of handling was worked out because the weight of each tower was far beyond the capacity of any available cranes in that locality.

The latest trend in the refining industry is the manufacture of 100 octane gasoline fuel designed especially for aviation work because of its increased power output and decreased fuel consumption. The old style 87 octane airplane fuel has 20 per cent less power and 12 per cent larger fuel consumption per mile than the new 100 octane fuel. The normal method of preparing this aviation fuel is by the blending of 50 per cent 70-76 octane straight run gasoline with 40 per cent commercial iso-octane and 10 per cent isopentane and a maximum of three cubic centimeters of tetraethyl lead per gallon. The segregation of high octane straight run gasoline is not new, but Foster Wheeler has taken an important part in the design of new equipment and processes for the manufacture of commercial iso-octane.



Note man in lower right indicating size of vessels turned out at Foster Wheeler shops.

One of the largest refineries specializing in iso-octane manufacture has installed two debutanizers to segregate a butane fraction of high degree of purity, this fraction being a charging stock for a combination polymerization and hydrogenation unit. The iso and normal butenes of this fraction are polymerized to iso-octene which is in turn hydrogenated to commercial iso-octane. In order to polymerize iso and normal butenes to octenes satisfactorily, it is necessary to segregate the multicomponent butane fraction with a high degree of purity. Butanes in the fraction do not enter into the reaction but do not affect it adversely as would the inclusion of lighter or heavier unsaturated hydrocarbons.

Commercial iso-octane leaving the low pressure separator of the hydrogenation units contains an excess of butane which must be fractionated out in order to give a product of proper vapor pressure. A stabilizer was installed for this purpose and the butanes so removed are used as a blending medium when desired.

Special care must be taken in the preparation of straight run gasoline used for blending to 100 octane aviation gasoline. Due to vapor pressure limitations, straight run gasoline is first passed through a debutanizer which uses a direct fired heater for the source of process heat. Following debutanization, blended gasoline is rerun to an endpoint of 265 to 295 deg. F., depending on the type of stock processed. The direct fired heater is also employed here to furnish required process heat. These direct fired heaters are designed especially to prevent overheating of the thin gasoline film next to the tube wall in order not to affect adversely subsequent treating operations.

Since debutanizers used in the process control the charging stock upon which all other equipment depends they were de-

The unit at the left was installed in 1928 for the Mid-Continent Petroleum Corporation for the atmospheric single flash fractionation of 10,000 bbl. of crude per day. To increase the yield of cylinder stock a small vacuum tower was installed to flash the residue from the atmospheric tower. In 1935 a two stage unit of the same capacity was installed, the original stack serving all three heaters.

signed for an unusually high on-stream time factor. Dual relief valves were installed on all tanks and drums of the debutanizer units inasmuch as these valves are one of the vulnerable parts of the system.

Another refiner also made extensive changes recently for the production of 100 octane airplane fuel, thereby making use of an available supply of a high purity butane-butylene fraction. In this plant Foster Wheeler installed a selective catalytic polymerization and low pressure hydrogenation unit, both under license from Universal Oil Products Company. The four sections of the unit included a caustic treating plant for the charging stock, a polymerization plant, a fractionating unit and a hydrogenation unit.

Sulphur compounds are removed from the butane-butylene fraction with caustic soda, leaving only a very slight trace which is insufficient to interfere with subsequent processes. Selective polymerization of the treated butylenes to iso-octenes is accomplished in a group of vertical reactors containing the catalyst. The polymerized product includes considerable excess butanes which are removed from the iso-octenes in a debutanizer. These butanes are removed overhead as vapor and are condensed and pumped to storage for later use as a blending medium. A second fractionating column is installed to remove overhead the iso-octenes, leaving as bottoms the higher boiling point fractions resulting from over-polymerization of a small percentage of butylenes. In the final section of the plant the iso-octenes are hydrogenated to iso-octanes in a low pressure catalytic hydrogenation unit. Product from the reactors consists of a commercial iso-octane which is ready for blending to produce finished 100 octane aviation motor fuel.

The processing and treating of petroleum derivatives at high temperatures—as distinct from general fractionation—is of constantly increasing importance. In the past separately fired superheaters have been used by a number of refiners to secure temperatures up to and exceeding 1,000 deg. F. In the last few years a new method has come into use for process heating at temperatures from 400 deg. F. to 700 deg. F. This involves the use of a diphenyl-diphenyloxide compound produced by the Dow Chemical Company and known as "Dowtherm." The major advantages in the use of Dowtherm are that its boiling point is 500 deg. F. at atmospheric pressure, 700 deg. F. at 88 lb. pressure and that it is susceptible to easy and accurate control in a system designed for its use.

In indirect heating systems Dowtherm is heated in the boiler and the vapors formed go to coils or jackets in the vessel to be heated where they condense. The condensed Dowtherm is then returned to the boiler either by gravity or by a return pump. The temperature can be controlled more closely with this indirect method of heating than with a direct fired still and any chance of film overheating is eliminated.

The operation is as simple and safe as that of a low pressure steam installation. Between 60 and 70 installations of Dowtherm boilers are now operating in the United States, several are about to go into operation in England and a unit is just being exported for operation in France.

A contribution to the art of high pressure heater construction was made in the development of a type of closure for the heads of high pressure vessels that does not depend upon heavy bolting for tightness. It is of more than passing interest to realize that the high pressures experienced in industrial work have actually reached a point where it is impossible to design and construct bolts sufficiently powerful to hold the pressure load and maintain a tight joint at the same time.

Long study and experiment resulted in a construction using small bolts to maintain a tight gasket joint, and shear blocks set in a groove to take the pressure load. This is known as the Lockhead construction and employs a flexible diaphragm which can move sufficiently to transmit the pressure load to a very heavy head block that is prevented from moving by the shear pieces engaging the forged steel head. Heaters of this type have been in power plant service for several years at pressures up to 2,000 lb. per square inch. They have been used in closing the heads of the largest evaporators ever built, 10 ft. in diameter. A dozen or more Lockhead shell and tube heat exchangers are in use by refiners and the results indicate that heavy bolted contructions will definitely be superseded by more easily handled designs.

Foster Wheeler, as may be seen, was very definitely in the refinery design and engineering business long before 1929. To maintain the company's position as well as to pioneer new processes on which, in earlier days, the corporation had built a substantial reputation, more extensive research facilities were required.

A new laboratory building was erected in 1929 and is fitted with extensive equipment for the physical testing of materials and making other physical, chemical and photomicrograph analyses.

The purely research activity has included investigations of many new processes which gave promise of better, or more economical, means for refining petroleum; also testing materials for strength, corrosion resistance and various specific chemical and physical characteristics. New processes and new materials of construction are continually being brought foward; they must be carefully and impartially investigated to determine their practical worth before installation.

Several new processes have been studied at considerable length in the laboratory, including solvent extraction and contact clay treatment. A new form of tower packing for use in any type of vapor-liquid contacting has been adopted after long and satisfactory investigation. It is of particular interest in connection with several difficult fractionation problems that are now coming to the front, such as the fractionation of straight run gasoline as a means of concentrating high anti-knock rating fractions, and the production of new derivatives which are obtainable by more extensive fractionating than has hitherto been practiced. This packing is made of corrosion resistant wire screen, perforated and formed

to give a regular pattern. It indicates a remarkable reduction in the height necessary for vapor to liquid contacting equipment.

In addition to engineering, research and construction departments, Foster Wheeler operates extensive shops in this country and abroad. These works are located at Carteret, N. J.; Dansville, N. Y.; St. Catharines, Ontario, Canada; and Egham, Surrey, England. They embrace all of the usual foundry, machine, forge and erection departments, but include in addition a non-ferrous tube mill and automatic electric welding machines of great capacity.

The main welding shop is more than 400 ft. long, served with speedy electric cranes and flooded with light through continuous window walls. Welding is practiced in several forms; electric fusion, by hand and automatically; acetylene gas; and hammer welding, as done in the forge shops. Cutting is by gas as desired.

A few years ago, when welding by direct current was believed by most engineers to be the only practical method, Foster Wheeler commissioned the General Electric Company to install the first complete, large scale, fully automatic, alternating current, fusion welding machinery in the U. S. A. The installation included a large stress-relieving furnace of most approved type, heated by gas through burners and controls arranged in two tiers along each side.

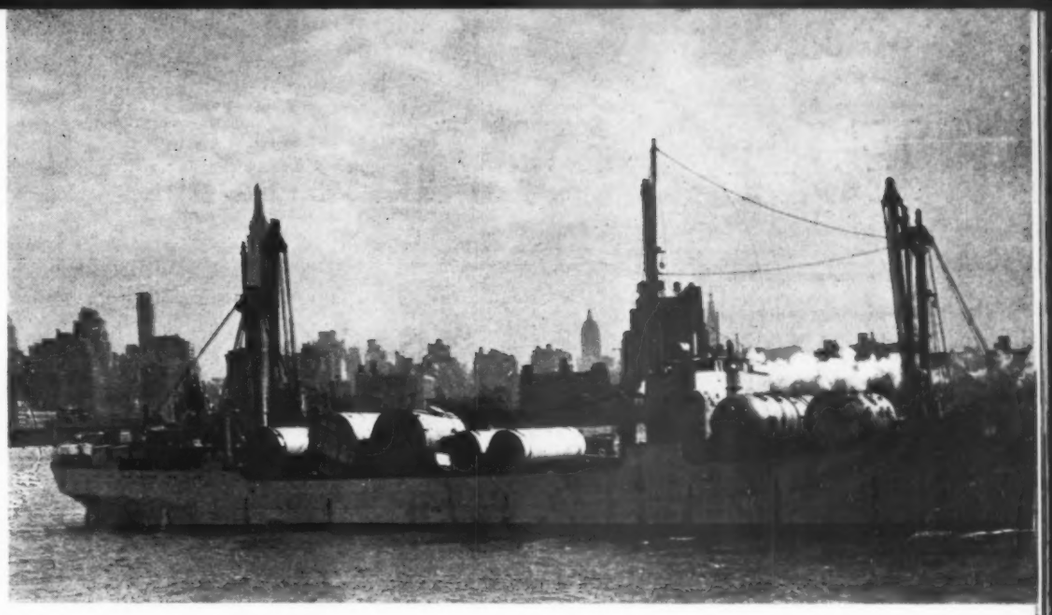
With this equipment the shop can weld the largest pieces that can be transported on railroads and in thicknesses up to 4¼ in. Even greater dimensions may be used but then the transportation must be by water. With the tide waters of New York harbor washing the shop pier it is not difficult to arrange for floating derricks to tie up there and load the heaviest pieces for ocean transport. The shop has many records to its credit, including the largest evaporator shells in the world. X-ray examinations are made of all welds requiring them and the negatives placed in permanent record file.

It is quite obvious that the only satisfactory proof of success in design, fabrication and construction will be found in the performance of the equipment. It may be interesting to cite one or two examples of records made that indicate notable success in the service for which the equipment was designed to operate. At the Ancap refinery, the single furnace, residual cracking unit for the Dubbs process was on stream continuously for 118 days. This is a world record for a single-furnace Dubbs unit and the shut-down took place only when the supply of charging stock had been exhausted.

The Mid-Continent Petroleum Corporation has set several records at its Tulsa refinery. In 1928 a single stage distillation unit was installed for the overhead recovery of cylinder stock from 10,000 bbl. of crude per day. A two stage unit for the same service was put on stream in 1936 and after a preliminary test run went into regular production on June 18th of that year. The unit ran continuously until June 6th, 1938, (718 days) charging an average of 13,500 bbl. per day although it was designed to handle 14,500 bbl. per day. Maximum daily throughput during this time was 16,250 bbl. This record is the more remarkable when it is considered that the best crude is charged to the atmospheric unit leaving the lower grades of crude for the two-stage unit. In addition to charging inferior crudes the two stage unit also handles all of the tank bottoms and various refinery slops. Pressable wax distillate recovered from both the atmospheric and two stage crude units is rerun after wax removal in an atmospheric distillation unit which remained on stream for 413 days and was finally shut down to terminate the run during a general shutdown of the heavy oil department of the refinery.

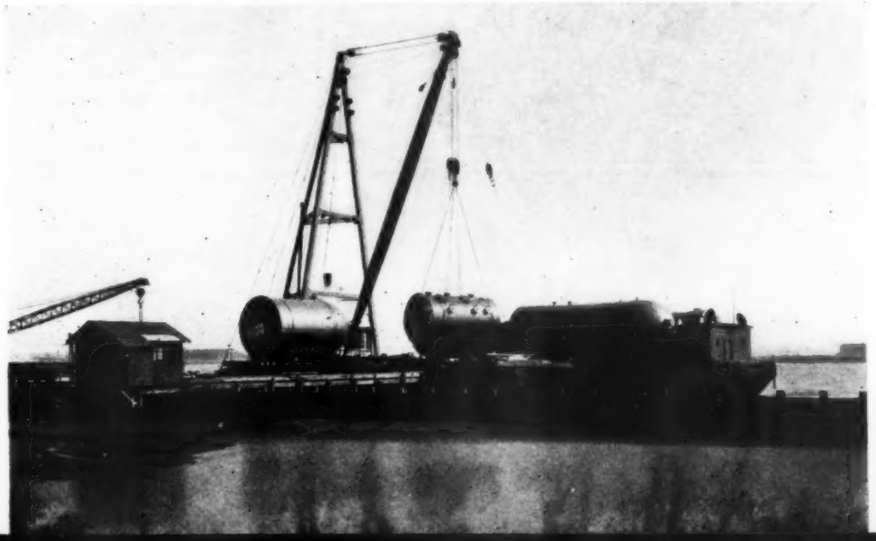
A complete picture of Foster Wheeler's position in the petroleum industry cannot be drawn from its refining activity alone. It has accomplishments in the transportation and production branches as well—not to mention refinery power plants.

In closing it may be interesting to bring this narrative up-to-date. The challenge of petroleum problems has been fully met. Some of the most important work of Foster Wheeler is currently in progress as indicated by a photograph of material being made and shipped to the West Indies for a large refinery addition. Equipment includes everything from foundations to final coolers for a 28,000 bbl. per day topping unit and a 18,200 bbl. per day rerun unit. Although classed as a topping unit, the crude charge will be fractionated to six specification products and a heavy residuum. Seven fractionating columns and three stripping columns together with five tubular oil heaters and other accessories make up a total of more than 10,000,000 lb. of material in pieces up to 75,000 lb. One of the photographs shows an entire boat load containing 2,500,000 lb. of steel products leaving New York in October. For this contract Foster Wheeler also had to provide for the transportation, housing and commissary of a hundred men 2,100 miles south of New York.



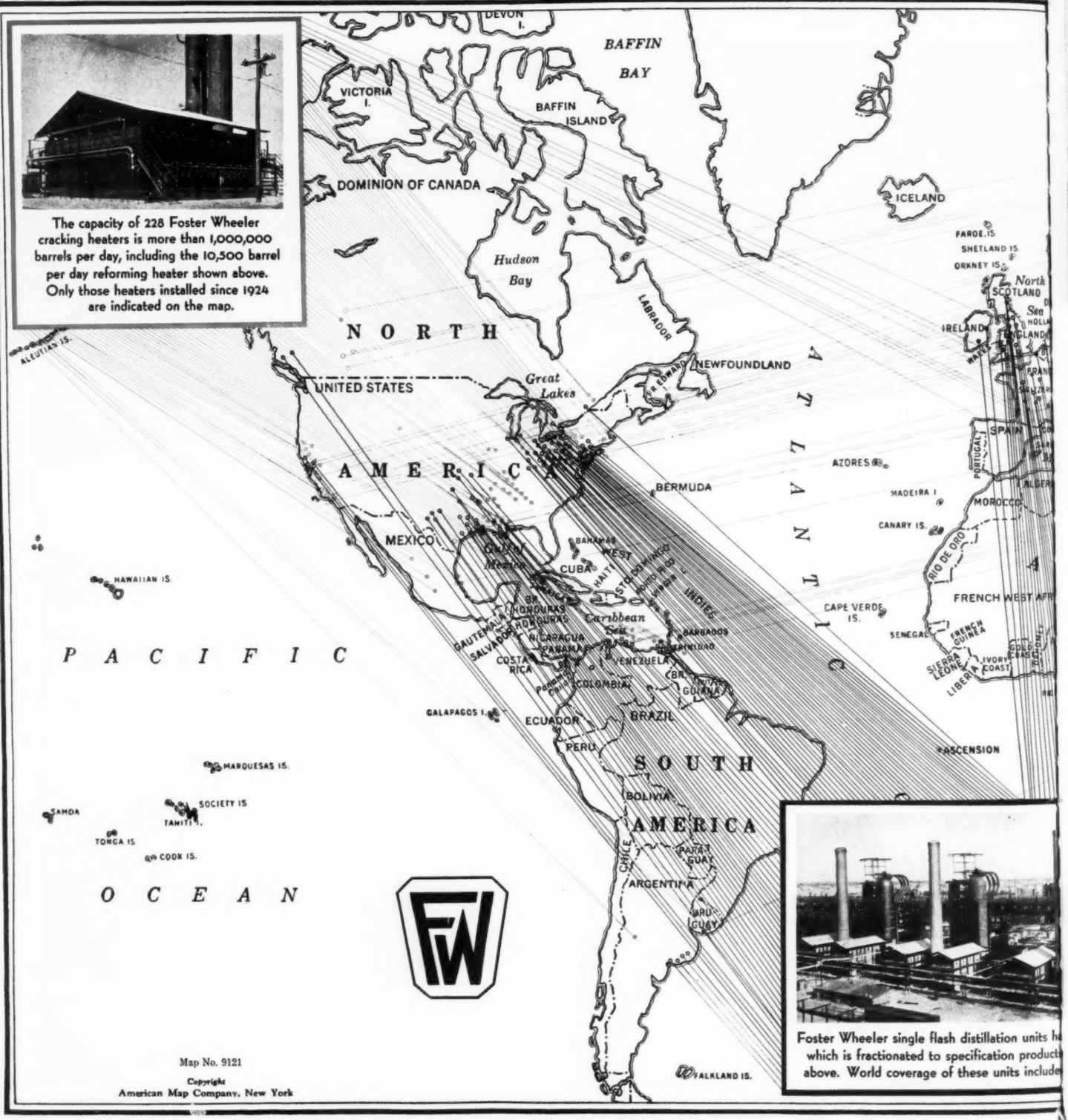
Cargo of heavy equipment leaving New York for the West Indies in October, 1938. This material will be used in an extensive modernization program in Curacao.

The tidewater facilities at the Foster Wheeler shops from which heavy equipment, as shown above, is shipped all over the world.



Foster Wheeler Refining U

The capacity of 228 Foster Wheeler cracking heaters is more than 1,000,000 barrels per day, including the 10,500 barrel per day reforming heater shown above. Only those heaters installed since 1924 are indicated on the map.



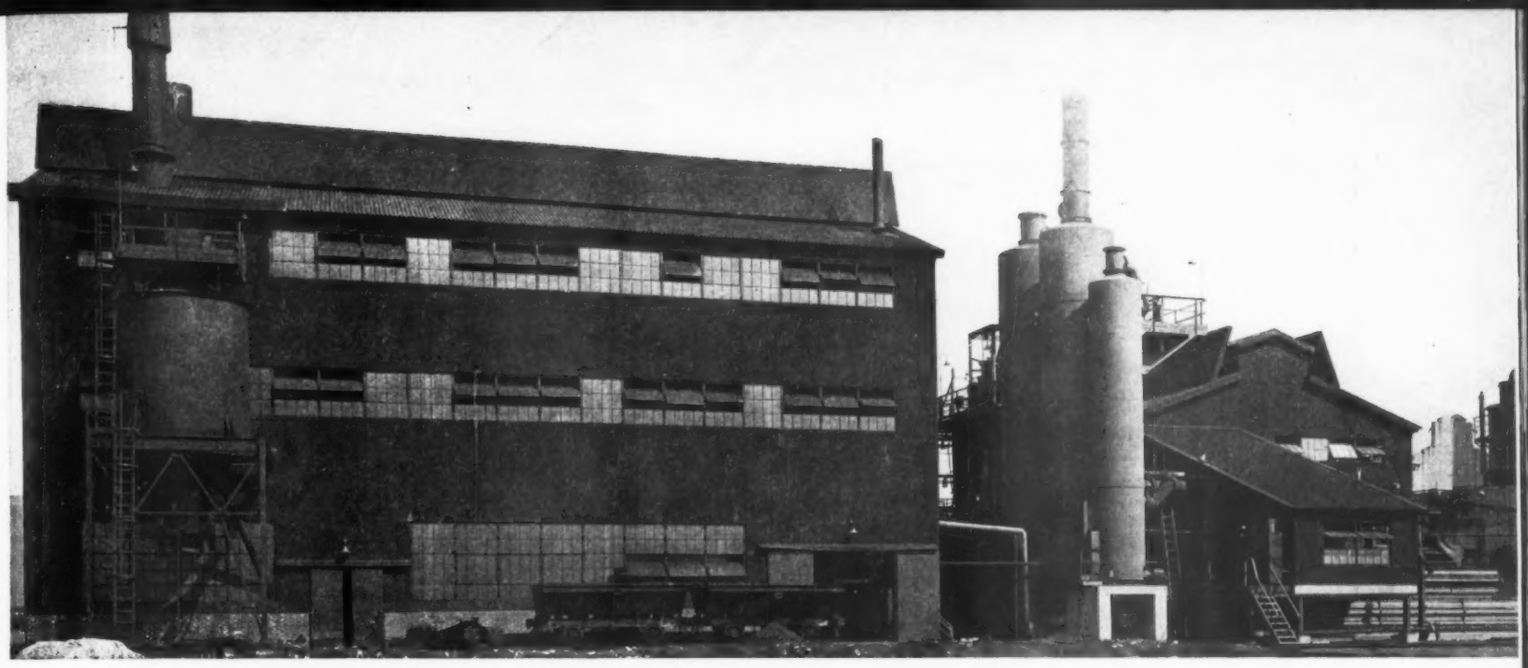
Map No. 9121

Copyright
American Map Company, New York

Foster Wheeler single flash distillation units h which is fractionated to specification product above. World coverage of these units include

FOSTER WHEELER CORPORATION
165 Broadway, New York
FOSTER WHEELER LIMITED
St. Catharines, Ontario

FOSTER W



The sludge conversion contact acid plant of the Atlantic Refining Company at Philadelphia.

ATLANTIC REFINING Operation Data for Sludge Conversion Contact Acid Plant

By W. B. Hart

Atlantic Refining Co.

THE sludge conversion contact acid process, among other applications, presents a means for the recovery of acid from petroleum refinery sludges. In its method for removal of the non-condensible hydrocarbons, a means of producing acid from hydrogen sulphide or sulphur is also available so that the acid lost in treating may be replaced and a balanced inventory maintained.

The process may be considered as made up of two distinct operations. The first of these has for its purpose the decomposition of the acid sludge; the purification of the gases resulting therefrom together with the introduction of the gases resulting from the burning of hydrogen sulphide or sulphur; the removal of the major portion of the water resulting from sludge decomposition and combustion of hydrogen sulphide and finally the delivery of the total volume of gas to the second operation. This consists of purifying the gases, converting the sulphur dioxide content to sulphur trioxide and absorbing the latter to acid in the desired form. This operation is the well-known contact acid procedure for sulphuric acid production.

The reader is referred, for a general description of the "Chemico" Sludge Conversion Process used in this plant, to the article by S. F. Spangler which appeared in the July, 1937, issue of Chemical & Metallurgical Engineering (Vol. 44, No. 7).

The process is covered by U.S. and foreign patents held by the Chemical Construction Corporation, N. Y.

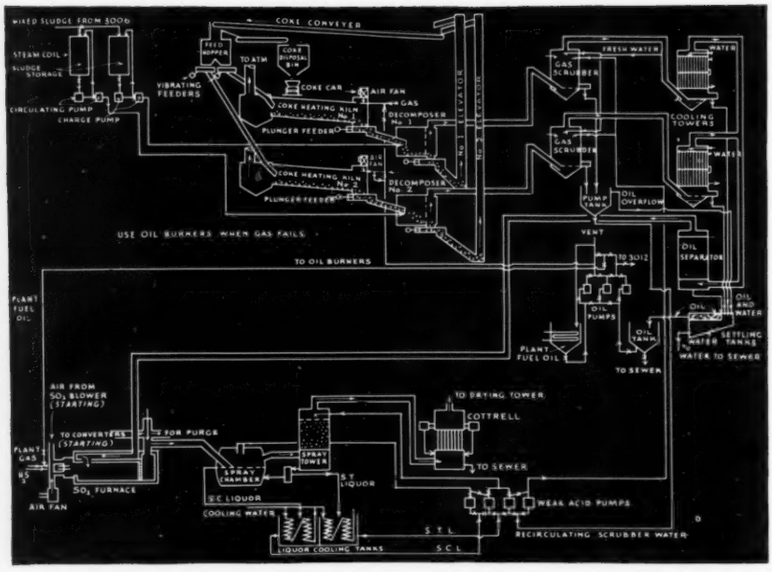
Later in this article the various steps will be discussed in some detail. Considerably more space will be allotted to the sludge decomposition than to the contact operation since the former is the novel feature and the latter a well-known chemical process.

ECONOMICS

During the past twenty or thirty years several processes have been developed for the purpose of recovering acid from petroleum refining sludges thereby to reduce treating costs. Usually these processes consisted of separating the sludge and concentrating the weak acid resulting. By these procedures from 40 percent to about 65 percent of the acid used on the oils could be recovered in form for reuse. But there remained a residual sludge which presented a problem in waste disposal. It could not be discharged to the plant sewers for fear of waterway pollution. It was impounded at some plants but this method was only a disposal postponement. Use as a fuel was generally adopted as a disposal method and since much of the original acid remained in the sludge, even after careful separation, this procedure was troublesome in densely populated districts.

The feature of greatest importance in economic considerations, however, is the greater recovery of acid from a waste material with the use of a second waste, i.e., hydrogen sulphide, as a raw material for replacing acid lost in treating. At Philadelphia, experience to date has been that an average of 89 percent to 90 percent of the acid available in the sludge charged is recovered. Acid available is determined by a standard laboratory determination and the plant recoveries are the result of several test runs. Conversion of hydrogen sulphide shows a yield of 94 percent. It can readily be seen that with even a few tons of hydrogen sulphide available each day, the refining processes are self contained as to acid supply.

The plant proper produces 98 percent acid and 20 percent fuming but is augmented by diluting equipment which makes it possible to produce any strength acid required. Grades produced at Philadelphia range from 80 percent strength to 20 percent fuming acid. This flexibility in the production of stronger acids is highly important, for in recent years, acids for treating petroleum products have tended toward higher concentrations. In many cases, even the lower required strengths cannot be made in concentrators due to the salt and carbon content of the weak acid as separated and charged. A reduction reaction causes breakdown of the H_2SO_4 to carbon dioxide, sulphur dioxide and water. Very discouraging yields and strengths of



Flow chart for the acid plant. No. 1.

concentrated acid are the result. Fortification of such acid to the higher strengths now in use result in excess inventories.

These features, with others of similar nature, prompted the installation of the sludge conversion and contact plant at Philadelphia. Design and construction was that of the Chemical Construction Corp. Work was started about March 1937 and the plant was placed in actual operation at the beginning of 1938. Operation experience extends over a period of about eight and one-half months.

THE PLANT

The plant at the Philadelphia refinery of The Atlantic Refining Co. is designed for a capacity of 65 short tons of 100 percent acid per 24 hour day, 50 tons from sludge and 15 tons from hydrogen sulphide. The design contemplates a production of 50 tons of 98 percent acid and 15 tons of 20 percent fuming acid (104.5 percent H_2SO_4). As by-products of the operation the design further contemplated 13 tons of a dry granular coke and 1300 gal. of recovered oil each 24 hrs. These design figures all resulted from a very comprehensive survey and analysis of the sludges encountered in 1935-36 and a forecast as to acid requirements over the next several years.

The first equipment item in the sludge decomposition operation is the coke heating kiln wherein coke is heated to be transferred to the decomposer which follows. The heat brings about decomposition of the sludge. The coke kiln is of the rotary horizontal cylindrical type with refractory lining. The coke is fed at the high end of the kiln by a vibrating feeder, comprising a sloping table located under a gate on the main coke bin. The table is vibrated at a predetermined rate by knockers, electromagnetically operated. The result is a well-controlled uniform rate flow to the kiln feed hopper which discharges centrally into the kiln end. Also at this end of the kiln is the flue and stack, offset to permit the central coke feed.

The original idea in operation of this kiln was to heat the coke by burning a controlled portion. Experience, with a plant placed in operation shortly before, indicated that this was impractical since the zone of combustion moved back and forth and constant temperature, so important to proper decomposer operation, could not be obtained. Realizing that the by-product oil would not be very clean, this also was rejected and lines and burners for gas were installed. The wisdom of this move has since been established by the ease of temperature control and uniform operation obtained. The kiln is fired at the low end so that the hottest coke is discharged directly into the decomposer. The kiln head at this end is movable back and forth, on tracks, so the kiln proper can be opened and examined. The kiln body proper extends into this head, the peripheral opening being sealed with sliding rings held in place with springs. The head itself remains stationary. From the bottom of this head the heated coke drops through a chute to a device called a plunger feeder by means of which the coke is introduced into the decomposer and which also divides the positive pressure side, i.e., the coke heating kiln, from the negative pressure side which includes everything from the decomposer forward to the blower.

The coke feed is maintained at a constant temperature by regulation of the gas fire. The amount of heat fed to the decomposer is varied by regulating the vibrator coke feed for a greater or lower quantity. Draft control is provided by a fan mounted on the kiln firing head and by dampers in the kiln stack. Little difficulty has been experienced up to the present with the kilns proper. Maintaining oil seals in the trunion bearings has been an annoying problem which is not yet entirely solved. Little if any difficulty has been encountered with the kiln drive which is a motor-pinion combination meshing a girth gear.

The plunger feeder, which is operated from a motor driven crank, is constructed of special heat and abrasive resisting alloys. It will be realized that in handling such material as heated coke, in the form of very hard small granules, there will be considerable wear at this point, and it is necessary to adjust clearances probably two or three times annually in order to prevent excessive coke losses. This is not a very difficult matter, however, since the entire equipment is so constructed that it is easily accessible and readily disassembled. The interior construction of the feeder is such as to act as a gas seal between the positive and negative gas pressure zones previously mentioned.

For a time after operation was first started, considerable difficulty was encountered with coke plugging the chute to the decomposer and thereby plugging the plunger as well. With better control and an all around smoother operation, this difficulty occurs more and more infrequently.

The decomposer is really the starting point of the operation, for into it the sludge is charged to be broken down into a mixture of vapors and coke.

It is a revolving drum or kiln, smaller than the coke heating kiln, chemical brick lined, with fixed heads in which the kiln cylinder rotates. The discharge end is removable to give access to the inside of the drum. Inside the decomposer is a specially designed cage-type tumbler whose function is to break up lumps of coke or coke and sludge mixtures that tend to build up and block the equipment. A decomposer block-up is occasionally experienced which requires opening the outlet plunger feeder and rotation of the cylinder until all lumps are worked through to the floor. It also has been necessary, on occasion, to remove the manhole cover plate on the outlet end head and break up large lumps with a bar. This condition will be referred to later.

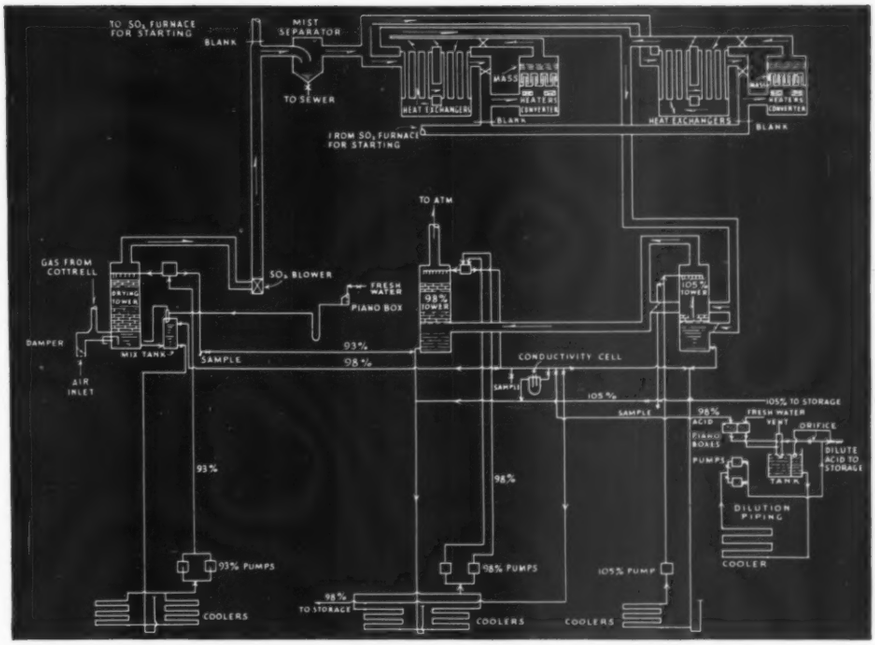
Simplicity in description will be served best by following the travel of the coke to a conclusion, discussing the sludge feed and then following the forward flow of the vapors. The coke charged to the decomposer, together with that resulting from the sludge decomposition, passes through a chute, in the bottom of the head on the

discharge end, into a plunger arrangement similar to that at the feed end. This plunger serves as a seal between the atmosphere and the negative pressure within the decomposer. It discharges the coke into the boot of the bucket elevator which raises and discharges it to a conveyor. The latter carries it forward above the kiln to the coke feed bin from which it is recharged into the coke heating kiln as previously described. The conveyor serves a second purpose also in that by its return travel it drags the excess coke from the feed bin to a cross conveyor for travel to the storage bin where it is measured as coke production.

The path of circulation of the coke may be summarized as follows—origin in the decomposer, thence to the outlet plunger; to the elevator; to the conveyor; the feed bin; the vibrator feed to the heating kiln, where it is heated and fed to the decomposer through the plunger-feeder. Excess coke is diverted to storage for use as fuel.

The sludge feed is of vital importance to smooth, satisfactory operation. It also presents the most serious operating problems. Based upon the evidence of previous experience with sludges being mixed for hydrolytic separation, there was every reason to believe that sludges resulting from treating naphthas, lubricating stocks, white oil stocks, etc., could all be mixed to a smoothly pumpable mass for charging. Based on this idea a sludge mixing plant was designed in which the lower viscosity naphtha sludges would be circulated by gear pumps through a pug-mill mixer and the heavier paraffine dropped directly to the mixer from a tank immediately above. The mixed sludge would then be delivered to an intermediate storage tank where it would be continuously circulated to prevent stratification and transferred as required to the charge tanks at the decomposing plant.

While sludge mixing equipment of this type is in successful use elsewhere, at the very inception of operation at Philadelphia it was found that the naphtha and paraffin sludges produced there could not be mixed without the separation of a large part of the mechanically held acid. This may be partly the result of pumping pressure. Nor could a sufficiently high circulating rate be obtained with the gear pumps to work the acid back into the sludge from which it had separated. This situation presented a problem which brought about a great amount of experimentation. The best solution seemed to be to set up two separate charging systems. In one the naphtha sludges were mixed by circulation and in the other the various paraffin sludges. Since there were two separate charging tanks at the decomposing plant, this procedure could be established straight through to the point where the sludge entered the decomposer.



Flow chart of the acid plant, No. 2.

The gear pumps at the mixing tanks were replaced with 12 in. x 8 in. x 18 in. reciprocating pumps to give increased capacity and the lines were rearranged. The pug mill was eliminated. Since this arrangement has been in operation much more satisfactory sludge mixing has resulted. Occasionally very heavy sludges cause tank and line blockage, particularly if good mixing sludges are unavailable. But with the average variety of paraffin, white oil, etc., sludges, a fairly satisfactory mixing procedure has been developed. With readily pumpable grades such as the sludges from naphthas, white oils and waxes, it is quite satisfactory.

Naturally the problem presented by the immiscibility of the two types of sludges carried on through to the charging pumps immediately ahead of the decomposer. Originally, under each charging tank there was a gear type circulating pump and a smaller gear pump, with variable speed control, for delivery to the decomposer. Since individual charging systems were necessary, a 7½ in. x 5 in. x 10 in. reciprocating pump was installed to handle naphtha sludges and the heavier sludges were handled through the gear feed pump. The larger gear pumps were retained for circulating. It was soon found, however, that these circulating pumps were of insufficient capacity. Much study and experimentation were again applied and a final procedure developed. It was concluded that the naphtha sludges did not require circulation so that the reciprocating charging pump was piped to take suction direct from the charge tank. The discharge was equipped with a set of short nipples to serve as rate controls with a by-pass to the suction for regulation. Three diameters of nipples were used, 1¼ in., 1 in. and ½ in. Although few felt that the ½ in. nipple would pass sufficient sludge for the charge rate, a test run on the naphtha sludge alone soon proved that only a partly open control valve gave an ample rate and that a practically perfect control was obtained.

The same idea was then gradually applied to the feed for the heavier sludges. The gear pumps were replaced with a 12 in. x 6 in. x 18 in. reciprocating steam pump which provided circulation in the charge tank. From the discharge of this pump a set of nipples formed a take-off to the feed line. Nipples of 1½ in., 1¼ in. and 1 in. diameter were used and the large pump became both the circulating and charging unit.

Separate lines lead from each charging pump to a water jacketed injector where the two types of sludge come together and enter the decomposer. The point of entry is above and slightly on the up rotation side of the coke entry point. With this arrangement the sludge immediately contacts the mass of heated coke and breaks down to coke, oil vapor, water vapor, carbon dioxide and sulphur dioxide. It is entirely probable that some sulphur trioxide and hydrogen also are formed and of course, since the decomposer is under negative pressure, some air leakage contributes oxygen and nitrogen to the gas and vapor mixture leaving the unit.

Operation of the decomposer is mainly controlled by the temperature of the outlet coke. This is maintained at 500-550 deg. F.

and really this temperature controls operation all the way back through the coke heating kiln. By maintaining the temperatures at the proper points and varying the coke rate with the rate of sludge feed, a fairly uniform set of conditions throughout the entire sludge decomposing operation results. Uniformity in this operation contributes in large degree also to the operation of the contact acid section, in fact, it is essential.

The rate of sludge feed is difficult to describe for it varies with sludge on hand, quality of the stock and other details. Ordinarily the amount of heavier sludges is not allowed to exceed the naphtha sludges charged in order to minimize the possibility of producing oily coke and other operating upsets. At times, however, the ratio advances to the point of charging heavy sludges alone. Typical charging rates are from 1200 to 1800 gal. of naphtha sludge with 900 to 1500 gal. of heavy sludge per hour. The combined feed is held under 3300 gal. per hour.

Vapors from the decomposer are drawn off through a flue to the gas scrubber overhead. This is a spray scrubber, five foot diameter by 18½ ft. high, lead and brick lined, and serves to knock down the coke dust carried by the vapors. The scrubbing water, having contacted the gases, is retained in a closed system. It flows from the scrubber to a closed separating tank where the coke settles out and is drawn off by a screw conveyor operated about once each shift. This coke is allowed to drain and is recovered for fuel. The water passes to a surge section of the tank from which suction is taken to the hard lead pumps for circulation. Water is added or wasted to maintain the proper balance.

Gases leaving the decomposer are under a pressure of about 2 in. to 2½ in. water. The temperature of the gas stream is about 500 deg. to 550 deg. F. Pressures and temperatures on the exit side of the scrubber are of the order of —3 in. to —3½ in. water and 250 deg. to 260 deg. F. No serious difficulty has been found in the operation of this item of the equipment other than at the seal where minor changes were made in the original design to overcome blocking of the outlet water line with coke dust.

The gases next enter the cooling tower which is in four superimposed sections, the two middle sections being tubular. The top section is equipped with sprays. The tower is approximately four feet diameter and 23 ft. high. The gases enter the bottom section and pass upward through the tubes and then into the spray zone, leaving from the top. The cooling water used in the tubular sections is wasted but the spray cooling water is recirculated, being returned to the coke settling box above mentioned.

The function of the cooling tower is to condense as much water and oil from the vapors as possible. The gas enters under about —3½ in. to —4 in. of water, and leaves at —4 in. to —4½ in. The entering temperature is about 250 deg. F. and the exit 120 deg. to 130 deg. F.

It should be stated here that the chain of equipment so far described forms one half of the decomposition equipment. An exactly duplicate chain is in parallel, with the exception of the coke elevator, conveyor and feed box. These items are common to both sides. The outlets of the cooling towers combine to form the inlet to the oil separator from which point forward only a single system exists.

The oil separator is a packed tower five foot diameter and 19 ft. high, and equipped with top sprays. The gases enter the bottom from the cooling towers and pass upward counter-current to the spray water. The latter leaves the bottom of the tower on its way to the settling basin in which the oil collects above the water and is skimmed for fuel while the water passes out to the sewer. At the bottom of the tower there is, of course, a liquid seal.

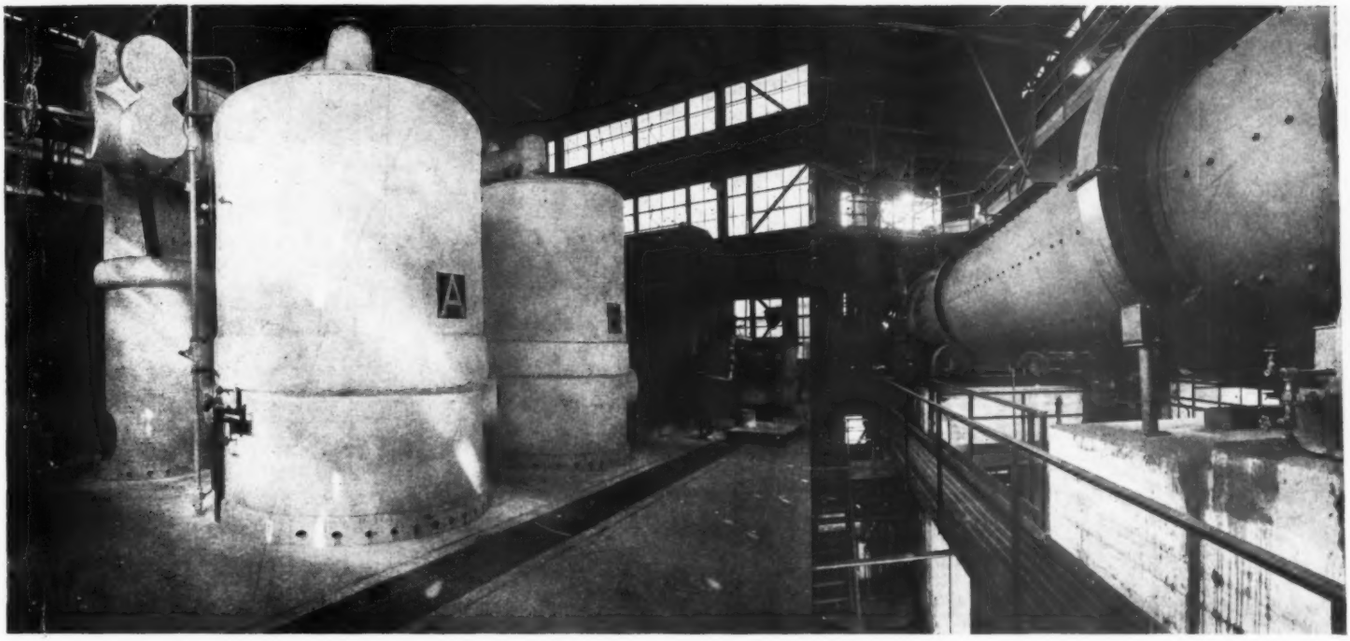
The functioning of the oil separator is very important, particularly from the standpoint of temperature. Experience has shown that the gas exit temperature must be kept at not above 90 deg. to 92 deg. F. or excessive hydrocarbon vapors will get by, overload the secondary furnace and cause excessive temperatures on beyond. The gases leave the oil separator under about —5 to —5½ in. water, passing on into the secondary furnace, or, as called by some, the SO_2 furnace.

This furnace, with its accompanying gas cooling equipment, is the final apparatus in the sludge decomposing operation. It is a horizontal, cylindrical tank type furnace, refractory brick lined and brick checker work baffled. The gases enter the top and pass forward toward the firing end over a muffle. They then pass down and back through the combustion space and the checker work to the outlet flue. The furnace functions to destroy by combustion any remaining hydrocarbons that could not be condensed and removed in the preceding towers. It operates at from 1400 to 1800 deg. F. depending upon operation rate and since there is not sufficient fuel value in the gases heat would normally be provided with fuel gas. However, since this is a very favorable point to introduce the hydrogen sulphide; this gas provides ample heat to maintain good combustion and a very satisfactory operation. The hydrogen sulphide is conducted to the plant from the gas purification plant through a four inch line encased in a six inch. Solenoid valves actuated by any serious loss of negative pressure serve as a safety precaution against hydrogen sulphide backing out of the furnace should power failure cause a blower shut-down. Recently, a burner has been devised that will handle both hydrogen sulphide or fuel gas, separately or mixed. This has been installed where the fuel gas burner previously had been and a burner for feeding melted sulphur placed where the hydrogen sulphide burner had been. With this combination acid can be made from sludge alone, sludge and hydrogen sulphide; sludge, sulphur and hydrogen sulphide; or sulphur and hydrogen sulphide separately or together. All these combinations have been used.

The operation of this furnace presents little difficulty but requires careful control at all times. It will be realized at once that if the hydrogen sulphide is not immediately burned to sulphur dioxide it will react with the sulphur dioxide present in the furnace, to form sulphur and the equipment beyond the furnace will be blocked. To prevent this a satisfactory excess of oxygen must be maintained. If the hydrogen sulphide flow is at all unstable, frequent tests are necessary to make sure the oxygen excess exists.

The gases entering the furnace from the sludge decomposition operation contain from 55 percent to 65 percent sulphur dioxide and carbon dioxide and but two percent to five percent oxygen. To keep the oxygen excess in the furnace at the necessary level, air is introduced by a small electrically driven blower. The air inlet is at the firing end and so arranged that there is immediate mixture with the decomposer gases as they pass down from above the the muffle. The amount of air admitted is controlled so that there is about a 10 percent oxygen excess, or, in case of irregular hydrogen sulphide flow, a 12 percent excess, to take care of any peaks. The gases leaving the furnace contain about 12 percent sulphur dioxide and are at around 1500 deg. F. in temperature. These gases must be cooled and the high water content, resulting from the combustion of hydrogen sulphide, removed. Both are accomplished in the spray chamber and spray tower which immediately follow the furnace. Gases enter the furnace under about —5 in. to —6 in. water pressure and lose about ½ in.

The spray chamber comes first in the system. It is a horizontal cylindrical tank, lead and brick lined. The gases enter at an angle from the center of the side, in such a manner as to impinge upon the surface of the water retained by the water level control. A water depth of about 36 in. is held. The space above the water is subject to the discharge from sprays that throw cooling water in every direction, not only to cool the gases



On the left is shown the interior of the converter building and, on the right, the decomposer building of Atlantic's sludge conversion and contact acid plant.

but also protect the brick-work. Originally this gas inlet was a rather complex structure lined with a carbon sleeve. This did not last, however, and experience has shown that a simple brick lined inlet with plenty of spray in the tank is much more satisfactory. The water used for the sprays is cooled by coil interchange and recirculated. An automatic overflow on the cooler box releases the excess to the sewer. The gases are cooled in the spray chamber to 140 deg.-150 deg. F. at which temperature they enter the cooling water.

Since making the structural changes in the gas inlet and installing additional sprays, little or no trouble has been experienced with the spray chamber. Twice it has been blocked with sulphur as a result of oxygen deficiency in the furnace but with increased experience on the part of the operators this trouble has been eliminated.

The spray tower immediately follows the spray chamber. It is a six foot diameter by 21 ft. high vertical packed tower equipped with sprays. The bottom of the tower is set at such an elevation that the water flows back into the spray chamber and also directly to the cooling coil box. This water is also recirculated to save the SO_2 content. The gas outlet temperature from the tower is about 100 deg. to 110 deg. F. and the pressure from —6 to —8 in. of water.

From this point forward the gas passes into the well-known contact acid system consisting of Cottrell mist precipitator, 66 deg. acid dry tower with its air inlet for controlling the sulphur dioxide concentration, the blower, beyond which there is positive pressure, the converters with their heat exchangers and the absorber towers for 98 percent and fuming acid make. These towers have the usual circulating pumps, lines and coolers common to contact plant equipment. None of this equipment has operated in other than a satisfactory manner. The vanadium catalyst used has shown an average of better than 96 percent conversion, in fact better than 97 percent has been experienced but at the risk of losing converter top temperature so it is not pressed for. The control of acid strength in the 98 percent acid tower, a most important feature in its relation to good exit stack conditions, is materially aided by the conductivity cell recorder while the interconnecting piping system has worked out very well.

Summarizing the operating experience at Philadelphia, the major difficulties encountered have all been in connection with the sludge decomposition operation. Largely, they can be traced to the unexpected condition of not being able to mix the two types of sludges to a readily pumpable mass for charging, and the necessity for carrying on, while operating, a process of development to establish the optimum procedure for charging each type of sludge separately. That this development is in its final stage is evidenced by the fact that plugged lines, plugged decomposers and similar feed difficulties are gradually disappearing and other troubles straightening out. It is true that all sludges made do not reach the plant. Some set up hard almost before they leave the treating agitator. But of those that can be delivered to the mixing plant, practically all are put into chargeable form and run. Of the hydrogen sulphide available, practically all is used and with sulphur as a balancing raw material a constant production rate is maintained. During the past ninety days there have been but two days shut down.

Plant Organization

Supervisor, Operating Foreman and Mechanical Foreman.
Sludge Mixing—1 Operator per shift.
Sludge Decomposition—1 Operator and 2 Helpers each shift.
Conversion—A Shift Foreman who is leader for all operations and an operator on each Shift. A laborer is employed Day Shift only.

Typical Analysis of Sludge

	Naptha Sludges Percent	Heavy Sludges Percent
Sulphur Dioxide Available	36	23
Equivalent 100 percent H_2SO_4	55	35
Non Condensible	1	0.3
Water	30	20
Oil	5	4
Coke	25	60

These analyses are reported on the basis of the standard test developed by the Chemical Construction Co. for determining the value of sludge as charging material.

Typical One Month Operation at the Philadelphia Refinery

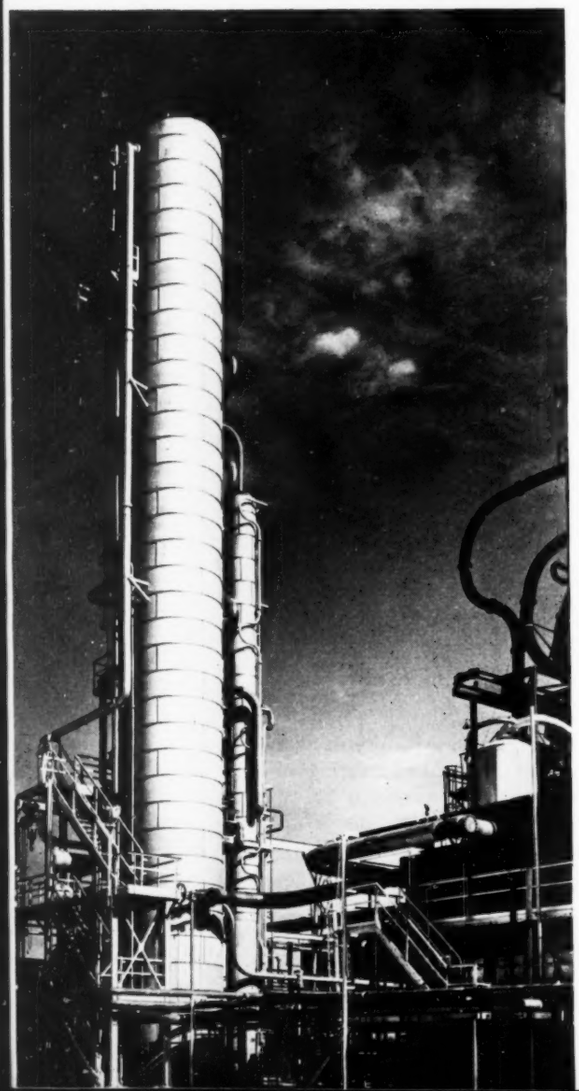
(During the period only one side of the decomposer house in operation.)

Naptha Sludge charged	3650 bbl.
Heavy Sludge charged	1760 bbl.
Hydrogen Sulphide Charged (100 percent)	120 tons
Sulphur Charged	106 tons
Labor	5040 Man Hours
Steam	2300 Thousands of Pounds
Power	94 Thousands of K. W. Hrs.
Water	84 Millions of Gallons
Fuels	2495 Thousands of Cu. Ft.
Production	1420 100 Percent Acid Tons

The acid produced is practically water white and is satisfactory in every respect.

Owing to a reduced treating schedule the plant has never operated at capacity for any given month. The above operation is at a 65 percent rated capacity.

WORLD WIDE MOVEMENT TOWARD REFINERY EXPANSION



Tendency Toward Location of Refineries Near Sources of Crude Supply Leads to New Construction and Enlargement of Existing Plants in All Quarters of the Globe. Growth of Smaller Specialized Plants Noted.

ACTIVITY in refinery construction during the past year has expressed itself largely in the expansion of existing plants, either by the addition of new units to broaden the range of products or by the replacement or enlargement of previously existing facilities to increase capacity. Further progress has been witnessed in the trend toward the expansion of refining capacity located close to bases of crude supplies and the world's largest plants are now in this category. At the same time the number of small refineries continues to grow, an increasing proportion of these being supplied with specialized equipment for the better utilization of their crude supplies.

Year by year the part played by cracking in providing the world's requirements of motor fuel becomes more and more important. In 1936 for the first time the production of cracked gasoline in the United States exceeded that of straight distillation and since then its lead has continued to grow. The following comparison shows the changes that have taken place in the relative positions of cracked, straight run and natural gasoline since 1930, the figures being percentages of the total output:

	Cracked	Straight Run	Natural
1920	14	83	3
1925	26	67	7
1930	37	52	11
1935	45	48	7
1938	49	45	6

As a result of the increased use of cracking the total amount of crude needed to supply world requirements of motor fuel and other products in 1938 will be roundly 2,000,000,000 bbl. instead of over 4,000,000,000 bbl. that would have been necessary without it. Thus cracking not only has added to the efficiency of the refineries in which it has been installed but has proved itself the greatest single factor in the conservation of oil resources.

The success of combination topping and cracking units constructed during the past few years and the increased efficiency demonstrated by these plants in operation has caused their number to increase steadily. In the larger refineries, and even in some of the smaller ones, the desirability of avoiding wastes and of producing a complete line of products has brought about the installation of polymerization units, solvent extraction processes for the production of lubricating oils and other special equipment for the treatment of distillates and residuals.

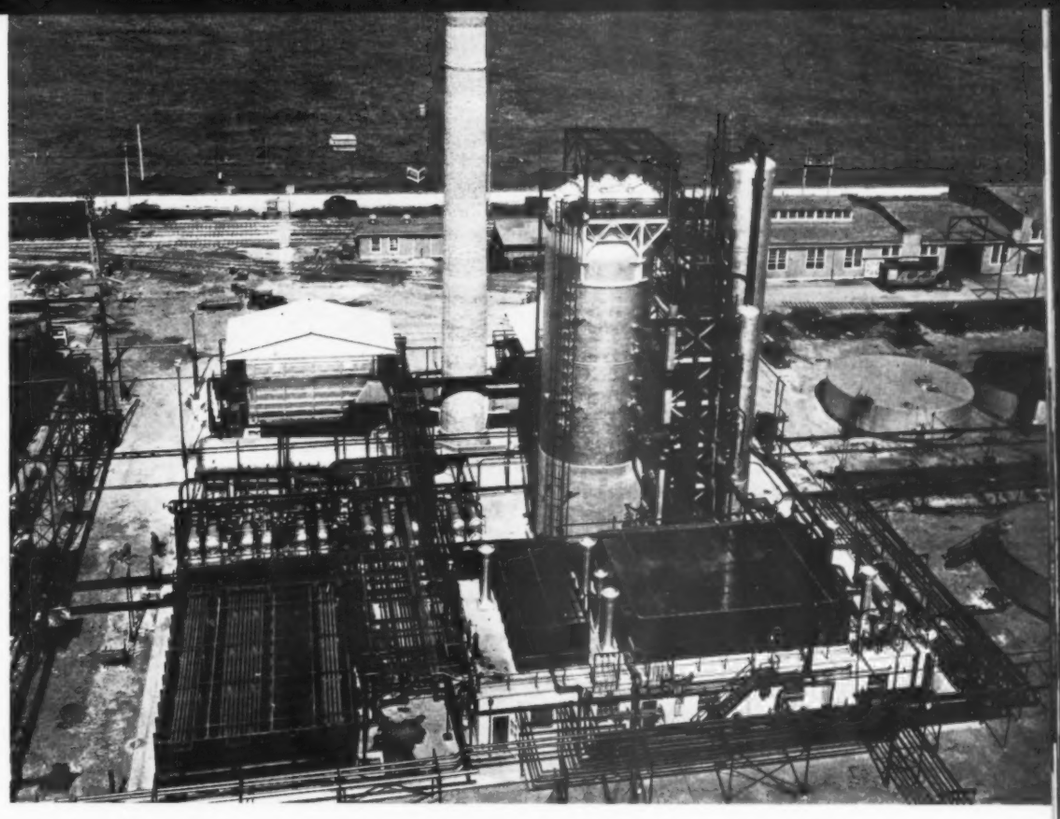
Desire for national self-sufficiency and the increasing attention paid to measures of military preparation have combined to stimulate the production of motor fuels from shales and coal. While this movement naturally enough has gained greatest headway in countries lacking in indigenous supplies of natura' petroleum such as Germany, Italy and Japan, the subject is receiving serious attention in many other countries in anticipation of the time when present oil deposits may prove inadequate to meet requirements. For several years England has had one great coal hydrogenation plant in operation at Billingham and several smaller plants using other processes. Two plants have been put in operation recently in France. Extensive plans for large scale recovery of oil from shales are now being put under way in Australia. Even in the United States, which still leads the world in production, the potentialities and costs of obtaining oil from coal are being studied in an experimental plant under the direction of the federal government.

For many years refining operations were concentrated largely in the United States. Even now the total refining capacity of American plants is 4,350,000 bbl. per day as compared with roundly 3,670,000 bbl. for the rest of the world. Within the past five or six years, however, building activity in other countries has been increasing and in 1938 the size and capacity of new plants and new units installed in these countries will equal or perhaps surpass that of similar installations in America. It is significant of the change taking place that the three largest refineries in the world are all located outside the United States.

INSTALLATIONS IN U. S.

Within the United States the improvement and expansion of refining facilities has been particularly marked in California which thereby has strengthened its position as second only to Texas in the number of its refineries and in the volume and value of their products.

Outstanding among the construction activities on the Pacific Coast has been the rebuilding of the refinery of the Richfield Oil Company at Watson, California, making virtually a new plant of greatly enlarged capacity on which $5,000,000 is being spent. The work is now approaching completion. Two combination topping and cracking units, each with a daily capacity of 33,000 bbl., have been erected.



Top left, the recently reconstructed Watson plant of the Richfield Oil Company; bottom, left, part of Socony-Vacuum's Paulsboro, N. J., refinery built by Alco Products Inc.; above, Port Neches, Texas, 16,000 bbl. per day unit of The Texas Company built by Alco.

Being the largest ever erected on the Pacific Coast, the six DeFlorez heaters serving these combination units have attracted widespread attention. These furnaces stand 132 ft. high and each has a diameter of 30 ft. Cost of the heaters and their auxiliary equipment is approximately $1,000,000.

Each of the combination units has a double Alcorn heater in addition to the three DeFlorez heaters. This group is designed to liberate 300,000,000 heat units an hour. The heaters of one unit contain approximately five miles of tubing of which about four miles is five inch alloy tubing. Charge capacity of the heaters is approximately 140,000 bbl. daily per combination unit.

There are seven separating and fractionating towers for each combination unit. The largest of these is roughly 13 ft. in diameter and 60 ft. high, weighing around 270,000 lbs.

In addition to the two combination units, construction now under way includes a Universal Oil Products catalyst type polymerization unit which, when completed, will have a capacity of 6,000,000 cu. ft. of gas daily.

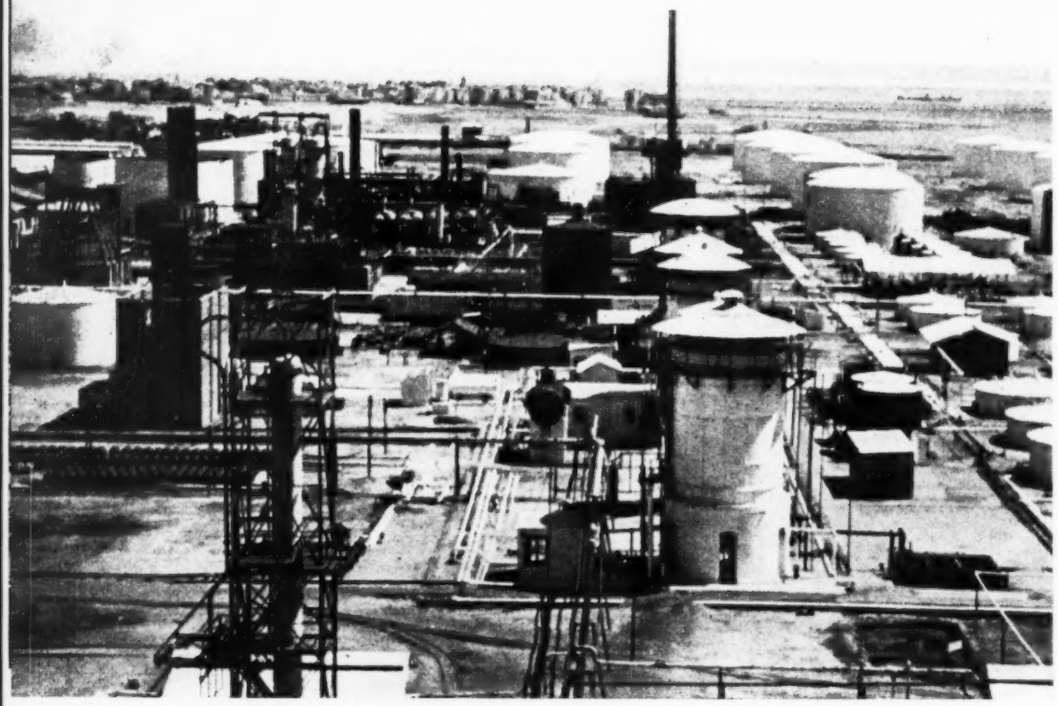
Another notable addition to California's refining equipment is the 14,000 bbl. daily capacity combination topping and visbreaking unit installed by Lummus Company at the Torrance plant of General Petroleum Company. This unit which has now been completed charges Ca'ifornia reduced crudes for producing a maximum yield of low pour gas oil.

Carrying forward the program of enlargement which Standard Oil Company of California has had under way for the past three years at its Richmond refinery an 18,000 bbl. crude distillation unit has been added. A 14,000 bbl. acetone benzol dewaxing unit and a lube rerun unit and a filtrol treating unit have been installed by E. G. Badger & Sons Company. Richmond's facilities include the first hydrogenation plant established on the Pacific Coast. With the polymerization unit completed last year and the recent additions mentioned above this is one of the most complete refineries in the country.

For Tide Water Associated Oil Company, Alco Products has constructed a polymerization plant to treat 5,000,000 cu. ft. of refinery gas daily and a modern three-coil cracking unit for the production of antiknock gasoline and high grade fuel oil. At the Martinez plant of Shell Oil Company a furfural unit has been installed by Lummus Company.

The Texas Company of California is installing at its Los Angeles refinery a 5,000 bbl. Stratcold acid treating plant at a cost of $250,000. Wilshire Oil Company has added to its refinery erected in 1936 a Dubbs reforming unit handling 4,000 bbl. per stream day.

Expansion of the refining facilities of Texas during the year has consisted largely



General view of the heating, crude distillation and asphalt units of the refinery in Egypt belonging to Anglo-Egyptian Oilfields Ltd.

in additions to the equipment of existing large plants. Among noteworthy developments have been the construction by Badger of a Houdry combination unit and Houdry cracking unit for Magnolia Petroleum Company at Beaumont, the first of these new units to be erected in Texas.

At the Port Arthur refinery of Gulf Refining Company Lummus has completed the extensive program of construction which has included a 22,000 bbl. combination cracking unit, cold acid and polymerization equipment for iso-butane, a high pressure hydrogenation unit for the production of iso-octane, a 6,000 bbl. rerun unit and a large acid treating plant. Continuous coking equipment was installed by Lummus at the Cincinnati and Toledo refineries of this company. The 22,000 bbl. combination topping and cracking unit built by Lummus for the Smith's Bluff refinery of Pure Oil Company has been completed and accepted during the year.

A 16,500 bbl. two-stage distillation unit, erected by Alco Products Company, has been added to the Port Neches refinery of The Texas Company. As this unit was designed to operate on crude oils some of which contain varying amounts of salt, the use of salt settlers was provided. Furnace tube surfaces in this unit were made with special attention to flexibility and permit a maximum of overhead products in either the atmospheric or the vacuum stages. The vacuum furnace is equipped with tubes which have an increasing cross-sectional area toward the furnace outlet, permitting subatmospheric pressures within the heating zone. The application of this principle insures maximum absorption of latent heat by direct fire and a close approach between the tube steel outlet and the vaporizing zone of the vacuum fractionating tower.

At the Baytown refinery of Humble Oil & Refining Company a unit constructed by M. W. Kellogg Company for deasphalting, dewaxing and acid treating in propane solution is now in operation and the same company is installing a 5,000 bbl. phenol treating plant for the solvent extraction of lubricating oils. The Kellogg Company also has installed at the Texas City refinery of Pan American Refining Corporation a third large combination unit having a capacity of 18,000 bbl. daily with clay treating. This unit is now in operation. For Duval Gasoline Company at Benevides, Texas, Kellogg has constructed a new type casinghead gasoline recovery plant embodying refrigeration which processes 6,000,000 cu. ft. of gas daily.

Standard Oil Company of Louisiana has added to its Baton Rouge refinery a propane dewaxing plant built by M. W. Kellogg Company. For the Empire Refining Company at Ponca City, Oklahoma, E. B. Badger & Sons Company have installed a pressed distillate rerun unit. The same company is constructing Houdry cracking units for White Eagle Refining Company at Augusta, Kansas, and for Lubrite Refining Company at East St. Louis, Illinois.

At the Whiting, Indiana, refinery of Standard Oil Company (Indiana) a 22,000 bbl. combination delayed coking and cracking unit erected by M. W. Kellogg Company is now in operation and a large iso-octane plant is now under construction. In Michigan a Houdry combination unit is being built by Badger for the White Star Refining Company at Trenton, Michigan, and another Houdry cracking unit is being installed by this same company for Sun Oil Company at Toledo, Ohio. At Ashland, Kentucky, a 7,000 bbl. atmospheric and vacuum pipe still is under construction by Lummus for the Ashland Oil and Refining Company.

In the reconstruction of the refinery of the Sinclair Refining Company at Wellsville, New York, recently damaged by fire a benzol acetone dewaxing plant of 4,400 bbl. daily capacity is being included. This unit, designed by Lummus Company, incorporates several recent refinements which result in marked economy of operation. It is to be completed in five months time.

Houdry cracking units are being installed by Badger in the refineries of Socony-Vacuum Oil Company at Brooklyn, N. Y., and Paulsboro, New Jersey, and a Houdry combination unit in Socony-Vacuum's Buffalo refinery. At the latter plant Badger also is installing a topping and vacuum pressed distillate rerun unit.

At Paulsboro an atmospheric distillation unit handling 7,500 bbl. per day of mid-continent crude to produce straight run gasoline, furnace oil, and residuum has been installed by Alco Products Company. The basic principle of flash distillation has been adhered to in the design of this unit, utilizing top and intermediate circulating reflux. The employment of top reflux circulation reduces condenser surface to a minimum and reduces corrosion from hydrochloric acid and hydrogen sulphide. Use of intermediate reflux permits a reduction of heat load at the top of the fractionating tower and gives a high final preheat temperature when the unit is being operated for a low percentage of residue. The heat which otherwise would represent excess reflux in the fractionating tower is thus utilized to reduce fuel consumption and less furnace surface is required because of reduced furnace duty.

At its Philadelphia refinery Atlantic Refining Company is installing a 20,000 bbl. crude pipe still with heaters and towers by Lummus. Another installation engineered by Lummus is a 3,100 bbl. crude topping still for the refinery of The Texas Company at Providence, R. I. A Badger-designed acetone benzol dewaxing unit has been added

to the refinery of Tide Water Associated Oil Company at Bayonne, New Jersey.

CANADA

Extension of the Turner Valley fields with consequent increase in output has resulted in the accumulation of crude stocks during the current year as transportation facilities were lacking and refinery equipment was inadequate to handle the increased production. On July 1 it was estimated that the wells then drilling, when completed, would raise the daily output to 100,000 bbl. while refining capacity in the district was under 40,000 bbl. As a result of this condition renewed activity in refinery construction is taking place in western Canada.

One of the most important of these projects was announced in June last by British American Oil Company. It provides for a refinery of 4,500 bbl. daily crude capacity with topping and cracking units, a treating plant, finishing still and storage for 500,000 bbl. of products to be erected at Calgary, Alberta. A full range of products, including gasoline, kerosene, tractor and Diesel fuel oils, domestic heating oils and roads oils, is to be turned out.

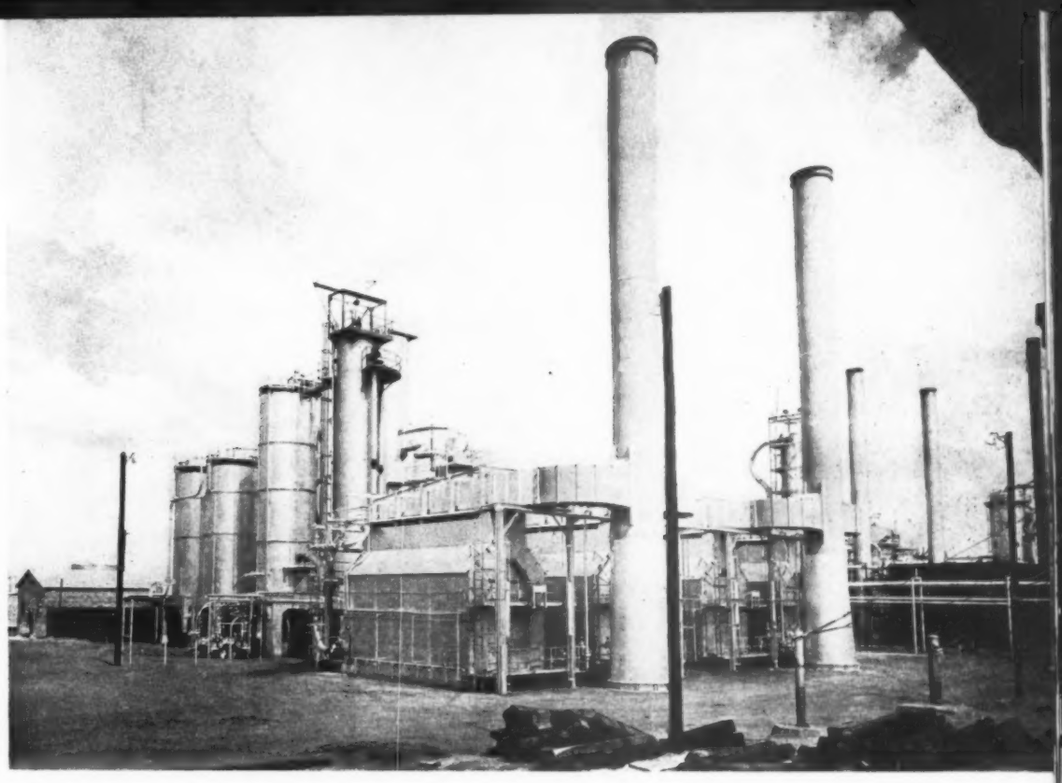
Other new enterprises include a 500 bbl. daily capacity skimming plant for Economy Oils Ltd. at Calgary, Alberta, a projected 2,000 bbl. plant for McColl-Frontenac Co. at the same place and another at Regina, Saskatchewan, and additions to the refineries of Imperial Oil at Regina and Calgary.

At Halifax, Nova Scotia, one of the significant developments of the year has found expression in the new combination crude topping and two-stage cracking plant including integral treating systems, erected by Imperial Oil Ltd. For several years the company has followed the principle of fully automatic precision control in all the new units constructed for the seven refineries which it operates in Canada. In the new plant at Halifax, however, this principle has been carried further than ever before.

The new unit probably is the most completely automatic refining installation that has been built by the petroleum industry. Its features include automatic control of feed rates, firing, liquid levels, refluxes, temperatures and pressures at all important points, including full automatic control of treating systems. Meters have been provided to record continuously the quantities charged and the yields of finished products.

Aside from the advantages of increased efficiency and economy in operation this automatic control ensures absolute uniformity of stocks produced.

One of the novel features of the Halifax plant, as of all other new units built by Imperial, is the centralization in one control room of the recordings of all automatic equipment. This makes it possible for the chief operator to determine the exact state of operating conditions at all times.



Cosden Refinery at Big Springs, Texas, showing the Dubbs unit. On the left may be seen reaction chamber, flash chamber and fractionating tower.

The particular unit referred to has an average daily crude charging capacity of 12,000 bbl. and is capable of processing either light or heavy crudes. The unit was designed by the technical staff of Imperial Oil Ltd.

Another part of the Western Hemisphere in which activity in refinery construction has been particularly notable is the British and Dutch West Indies. For the past five years, since the imposition of an import tax on crude oil made it impracticable to ship Venezuelan crude to the United States the great refineries of the Royal Dutch Shell group at Curacao and of Lago Oil and Transport, a subsidiary of Standard Oil Company (N. J.), at Aruba have been undergoing reconstruction and expansion which has placed them among the three largest refineries in the world, the third being the great Abadan plant of the Anglo-Iranian Oil Co. in Iran.

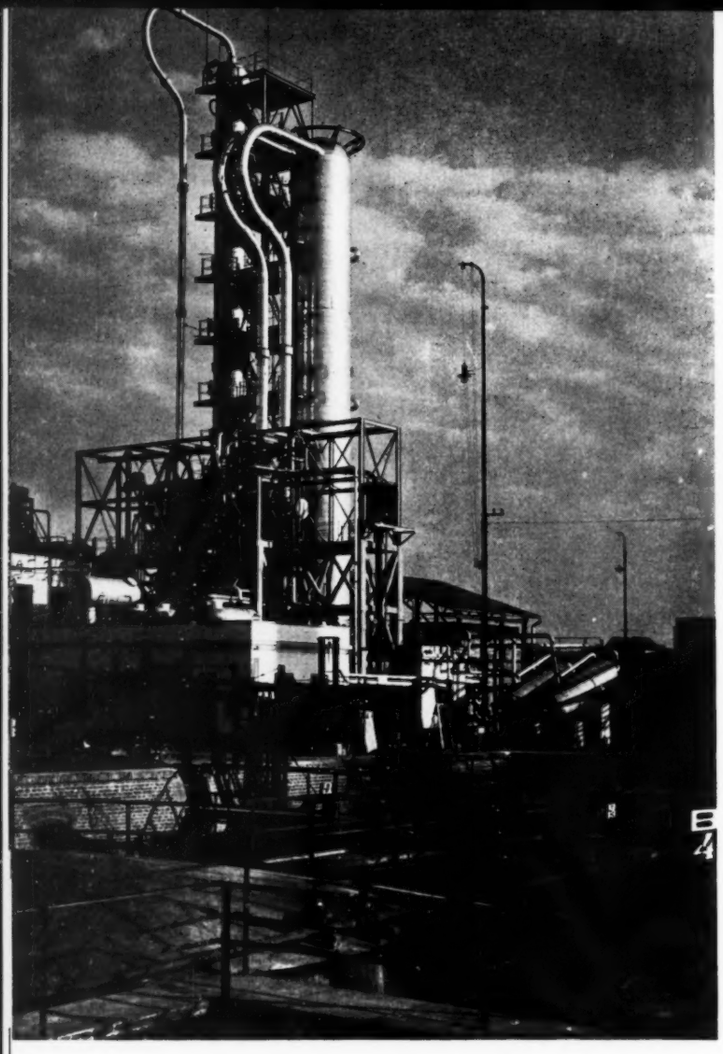
WEST INDIES

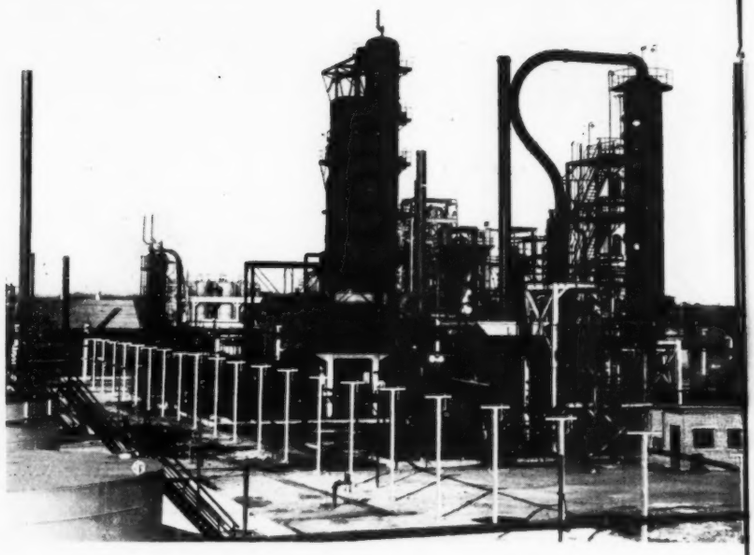
At the present time the Aruba refinery has an average current running capacity in excess of 240,000 bbl. daily and produces a great variety of finished products, consisting of many grades of naphtha, refined oils, high speed Diesel oils, heavy marine Diesel fuels, and residual bunker fuel oils.

Originally comprised only of topping stills, combination cracking units and acid finishing facilities for the cracked naphthas, the refinery of today has, supporting the cracking units and their attendant finishing facilities, four atmospheric distillation units having a capacity ranging from 7,000 to 12,000 bbl. daily each, depending on service, a fifth atmospheric distillation unit with a capacity of 16,000 bbl. per day and a two-stage atmospheric vacuum distillation unit with a capacity of approximately 30,000 bbl. daily. These units are employed in various services, primarily for the production of such by-products as refined kerosene, high speed Diesel oils and lube oil base stocks.

The combination atmospheric vacuum distillation unit is run for the most part on low cold test Colombian crude. This crude has natural characteristics ideally suited for the manufacture of Diesel oils for high speed engines and a low cold test, high viscosity lubricating oil stock. The high speed Diesel oil is further processed to remove natural acidity and finished for the trade in the Aruba plant. Because of its extremely low cold test it has been found ideally adapted to Diesel engines used in aviation, for which reason the Graf Zeppelin and the ill-fated Hindenburg have used this Diesel oil produced at Aruba to the exclusion of all others. The Aruba refinery does not have facilities for the manufacture of finished lube oils and none is produced there, the lube oil distillate from the Colombian crude being shipped to other refineries for finishing and blending.

The atmospheric distillation units are employed primarily in the running of somewhat lighter grades of crude of which the crude from the La Rosa field in Lake Maracaibo, of about 25 gravity, is typical. These crudes are run for the production of normal naphtha, kerosene and gas oils, the bottoms from this operation going to the combination





Left, distillation tower of the Polmin refinery designed and built in Poland by Foster Wheeler; above, Lube rerun and Lummus unit of the Campana refinery of the Compania Nativa de Petroleos S.A. in Argentina

cracking units for the production of additional cracked naphtha and to reduce the viscosity on fuel oil residues. The natural kerosene or refined oil cut in these crudes is in itself somewhat inferior to the same distillates from most Mid-Continent crudes in the United States. To correct this deficiency in quality Aruba has constructed a sulphur dioxide extraction plant of the Edeleanu type designed by Badger, having a capacity to handle in excess of 10,000 bbl. per day kerosene distillates. By this process the unsaturates are extracted, leaving a finished kerosene of the highest possible paraffinicity.

These atmospheric units are also occupied part time in the preparation of various asphalt stocks from different specially selected crudes and these stocks are shipped to other refineries close to market outlets for final finishing. Aruba does not produce any finished asphalt for the trade because of the difficulty of transporting finished asphalt in bulk tankships and the expense which would be incurred in drumming the asphalt for transportation by regular cargo ship. For this reason the base stocks are produced at Aruba and the finished asphalt at points close to consumption where bulk delivery by tankcar is possible.

Facilities are just being completed at Aruba to permit the manufacture of aviation base gasolines and aviation blending agents. The facilities for the blending agents consist primarily of extracting isobutylenes from the light ends of the various cracked naphtha streams, passing these butylenes through a polymerizing process for the production of dimer and in turn hydrogenating the dimer into iso-octane which is one of the best blending agents used today for the production of 100 octane aviation gasoline.

In addition to the facilities outlined above for the production of iso-octane, there is also being constructed the necessary sweetening, rerunning and stabilizing equipment for fractionating from selected normal naphthas a gasoline falling in the aviation boiling range with a clear octane of 70/72.

Among the recent additions to Aruba's equipment are a 9,000 bbl. gas oil cracking unit and a hydro-codimer unit, both installed by Kellogg Company. Another new feature is a crude distilling unit designed by Alco Products Company to process 16,000 bbl. daily of La Rosa crude or alternately to distill 15,000 bbl. of heavy pressure distillate.

When operating on crude the unit produces streams of naphtha, refined oil, gas and residuum. The side streams of refined oil and gas oil are removed from selected trays in the fractionating tower and are stripped to specifications in separate strippers. The residuum, after stripping in the lower part of the tower and after heat exchange, flows to storage.

The general design of this unit was based on minimum operating costs. A high degree of preheat is obtained on the crude, due to high flashing temperatures. By the use of intermediate reflux below the gas oil the tower diameter required at the top is the same as that below the gas oil.

The most immediate projected addition to Aruba's equipment is the enlargement of tankage capacity for the smoother and more efficient handling of its very large operations.

Increasing production in Trinidad, British West Indies, has led to the enlargement of two of the principal refineries in the island, practically doubling their capacity. One of these is the plant of Trinidad Leaseholds, Ltd. which will be described in detail in a subsequent article. The other is that of United British Oilfields of Trinidad situated at Point Fortin in the southwestern portion of the island. This plant heretofore consisted of a crude unit with a capacity of 17,000 bbl. daily, capable of making the usual range of straight run products. It was erected in 1933.

In addition to the main unit the plant is equipped with a small atmospheric asphalt plant, an Edeleanu plant for the manufacture of high grade kerosene and Diesel fuel and a plant for the manufacture of bitumen emulsion.

Of the extensions now under way the principal one is the erection of a new crude unit and gasoline stabilizer which will approximately double the capacity of the existing refinery. The unit is of European design and embodies the latest technical developments. Much of the equipment required will be purchased in the United Kingdom and the balance will come from the United States and continental European countries.

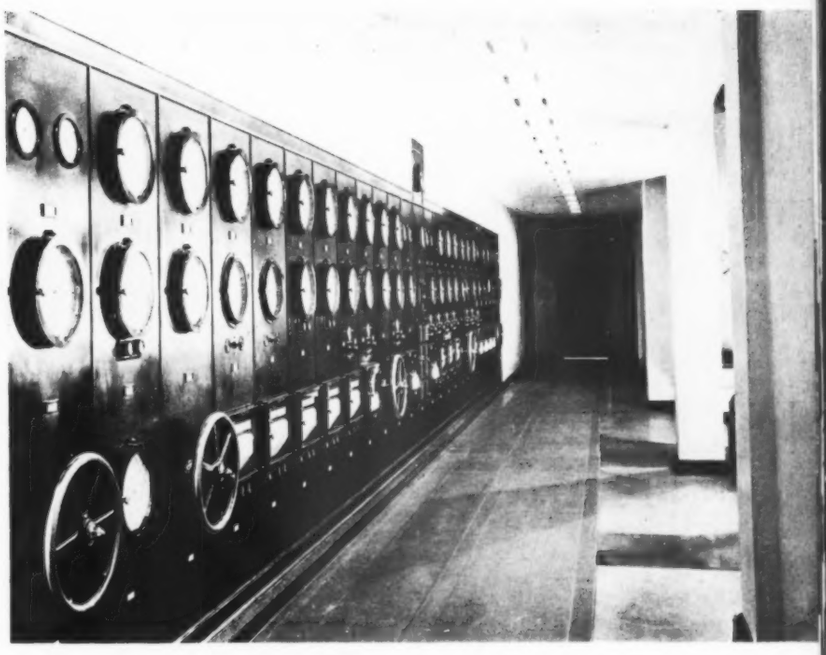
The increase in capacity will necessitate

a corresponding increase in tankage and in steam and power facilities. The refinery receives much of its crude by pipeline from its own fields and purchases the remainder from other Trinidad producers. Its products for the most part are exported in bulk.

Belot refinery of Standard Oil Company of Cuba, located across the bay from Havana, is engaged in remodeling two of its three tube and tank coils for cracking and the third for operation in a pipe still unit. The pipestill and cracking coils will be arranged to operate as a combination unit to top crude and crack residuum in a recycling operation. At present crude is reduced in atmospheric stills and the bottoms processed in a vacuum still where lubricating oils are separated. In order to improve the lubricating oil operation a new vacuum tower will be provided to operate with the pipe still. The asphalt plant has been extended by additional facilities which now permit the manufacture of cut-back asphalt.

The Belot refinery operates on crude imported from the United States and supplies the Cuban market with a full line of white products in addition to lubricating oils, greases and asphalt.

Extensive plans for the rehabilitation of Mexico's refineries which had been prepared by the operating companies were suspended by the government's confiscation of the oil properties in March last. Since then it has been reported at various times that the government itself was negotiating for the construction of one or more plants to be paid for by shipments of oil. The difficulties surrounding any such barter arrangement apparently have prevented the conclusion of definite contracts up to the present time.



Centralized control room of the automatically operated combination crude topping, two-stage cracking unit with integral treating at the Halifax, Canada, refinery of Imperial Oil Ltd.

SOUTH AMERICA

In continental South America a substantial increase in refining facilities has taken place in Argentina including additions to several plants of the YPF. The new refinery of this company at San Lorenzo was completed and put in operation early in the year.

Rebuilding of the plant at Campana of Compania Nativa de Petroleos, S.A., subsidiary of Standard Oil Co. (N. J.) has been going forward since the original plant was destroyed by fire in 1934. At the present time Campana is reconstructing and enlarging the gasoline recovery plant and installing facilities for dewaxing overhead stocks in the lubricating oil plant. Other new equipment installed includes a two-stage Lummus pipe still, a vacuum rerun unit, new shops and storage tanks. Consideration is now being given to the augmenting of power facilities by installation of boilers and a turbo generator.

At the Bahia Blanca plant of Compania Nativa improvements to the gas plant have raised the yield and quality of naphtha. At the Manuel Elordi plant of Standard Oil Company of Argentina extensive housing and sanitary improvements have been installed for the benefit of employes.

The refining situation in Brazil has remained in a state of uncertainty since the issuance early in the year of a decree placing the petroleum industry under the direction of a National Council. Formerly Brazil imported all its requirements in the way of petroleum products. Then its policy was changed and heavy duties were laid on imported products to encourage the building of refineries. Several small plants were erected as described in previous issues of WORLD PETROLEUM and in 1937 Standard Oil Co. of Brazil began the construction of a large modern refinery in Sao Paulo. At the time of the nationalization decree, which required that all petroleum enterprises should be owned by Brazilians, the plant was about 80 percent completed. Since that time construction work has been suspended pending a clarification of the government's oil policy.

With the growth of production in eastern Venezuela plans have been prepared for a modern refinery in that area and it is reported that construction will begin shortly. This new plant is to be built by Standard Oil Co. of Venezuela near Caripito where the company already has in operation a topping plant handling 4,200 bbl. daily of eastern Venezuelan crude to supply gasoline and gas oil for producing operations and for the local trade. The projected construction will include a large visbreaker unit capable of processing approximately 30,000 bbl. daily of Quiriquiri type crude and will produce naphtha, heavy marine Diesel fuel and residual bunker fuel. The products from this plant will be shipped to export markets and will be loaded out on ocean going tankers which will arrive at Caripito via the Gulf of Paria and San Juan River.

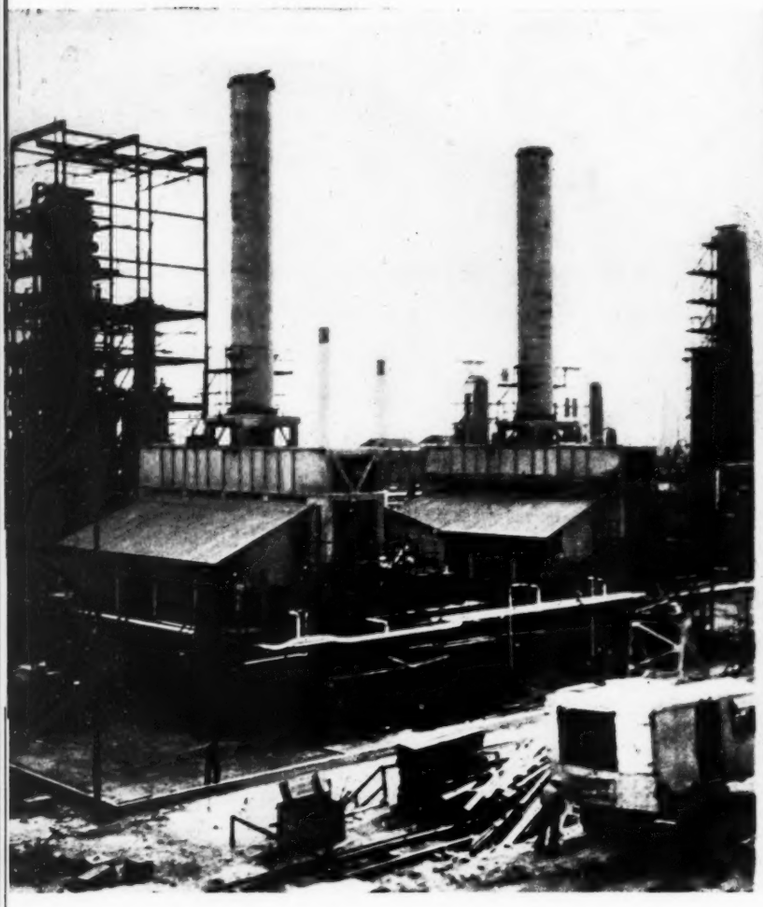
At La Salina where the Compania de Petroleo Lago operates a topping plant of 7,200 bbl. daily capacity it is reported that a pipe still and cracking unit are to be installed. Extensive improvements amounting to a doubling of capacity are also being made by the Shell interests in the refinery at San Lorenzo.

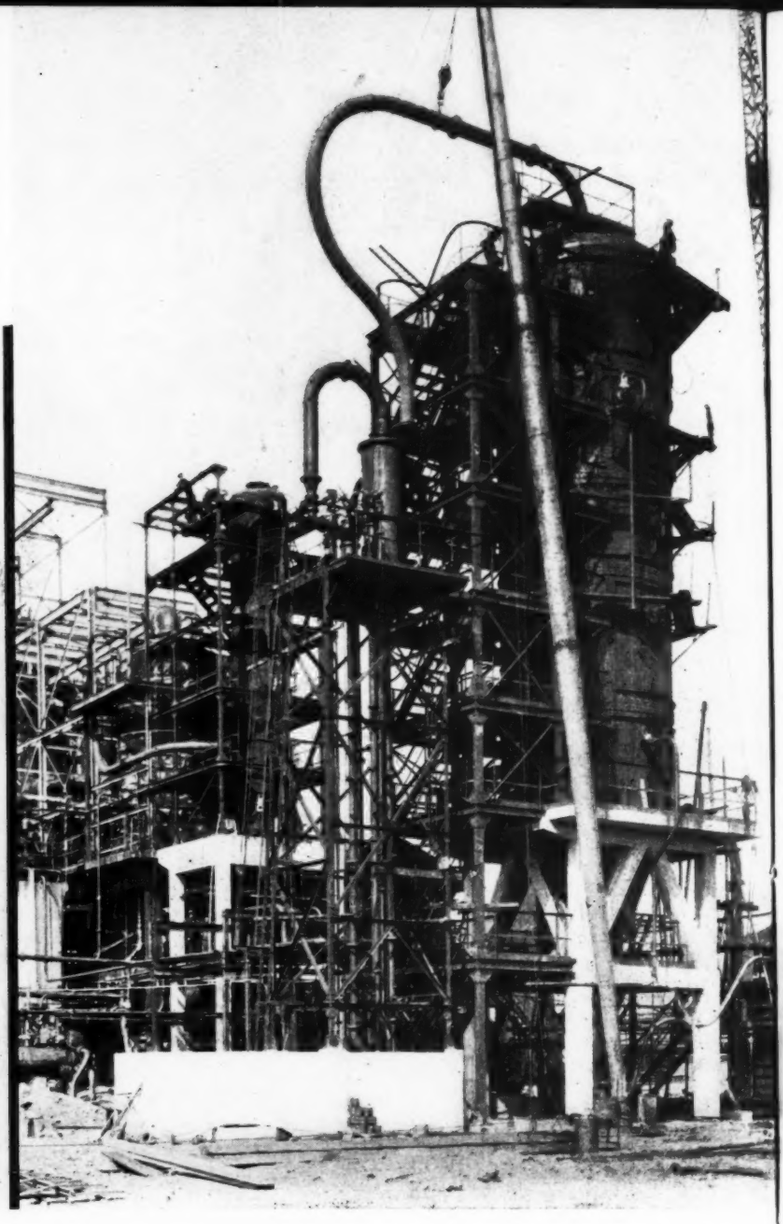
EUROPE

Refinery work in Europe has covered a wide range of activities. Carrying forward its plans for national self-sufficiency in motor fuels and other products Germany has greatly extended the output of its hydrogenation plants while actively continuing the development of other synthetic and substitute fuels. These developments will be fully described in a subsequent article. Traveling along the same path Italy has pushed ahead the construction of its two great plants at Bari and Livorno to the point where these are practically complete and are undergoing tests. Italy's plans for supplying its requirements are outlined in an article in November WORLD PETROLEUM. The concrete application of these plans in newly constructed plants will be described later.

While France is well provided with modern refining plants several important additions to existing equipment have been made. Among these are a 14,000 bbl. com-

Below, furnaces of the new cracking unit of the Aruba refinery; right the asphalt pipe still under construction at the Agwi Petroleum Company's plant at Fawley, England.





bination unit for Cie. Francaise de Raffinage at Martigues and a 4,000 bbl. naphtha reforming unit for the Soc. de Raffinage des Huiles de Petrole at L'Avera, both designed by M. W. Kellogg Company. A 13,000 bbl. reduction unit was designed and engineered by Lummus Company for the Normandy refinery of Cie. Francaise de Raffinage.

A vacuum unit installed by Alco Products Company for Soc. de Raffinage is unusual in that it was designed for any one of three uses: (1) As a vacuum reducing unit, (2) vacuum distillation unit, or (3) an atmospheric distillation unit. When operated as a vacuum distilling unit it charges reduced Iraq crude and produces gas oil, cracking stock, slop oil and residuum. Operating as a vacuum unit it charges reduced crude and produces gas, gasoline, cracking stock and asphalt.

In order to accomplish these results it was necessary to design for pressure operation in the one case and for high vacuum operation in the other. Fittings had to be provided which would give flexibility in changing the flow from series operations under pressure to a series parallel flow under vacuum for production of lubricating oil distillates.

The furnace design is such that this flow can be easily changed by replacement of cross over connections so fabricated that they can be readily replaced and the installation of U-bends for the roof tubes which give a four to carry flow.

During the past few years a modernization program, now practically completed, has been carried out at the Telejean refinery of Romano-Americana in Roumania. It has included the construction of a crude pipe still of 12,000 bbl. daily capacity and a new gas plant. At the same time the cracking coil was reconstructed and a new furnace added. This new construction permits the running of 16,000 bbl. daily of paraffinous crude through the crude stills and cracking of 50 percent of bottoms in the cracking coils. At present the refinery's capacity is rated 20,000 bbl. daily but additional cracking equipment would step this up to 30,000 bbl. Extensive additions have been made to the company's shops and recreational facilities have been installed in the employes' residential area.

Other improvements in Roumanian refining equipment include a catalytic polymerization and iso-octane plant installed by Creditul Minier at Ploesti and a polymerization plant for Redeventza at the same place.

Political uncertainty has helped to delay consideration of new construction in eastern Europe but proposals have been put forward for the erection of a refinery in Bulgaria by local capital with government assistance. Another project which seems logical in view of recent discoveries of new fields at Lispe in Hungary contemplates the erection by the government of a topping and cracking plant with a throughput capacity of 30,000 tons annually at an estimated cost of $750,000. The site proposed for the plant is on land owned by Ungarische Hydrobenzin A.G.

"Polmin" refinery, Poland, which is the

largest in the country, has rounded out its equipment by the construction of a two-stage distillation unit of the Foster-Wheeler type. This gives a greater yield of white products than the stills formerly used while preserving a suitable oil fraction as well as a good quality asphalt residue suitable for road making and for commercial purposes.

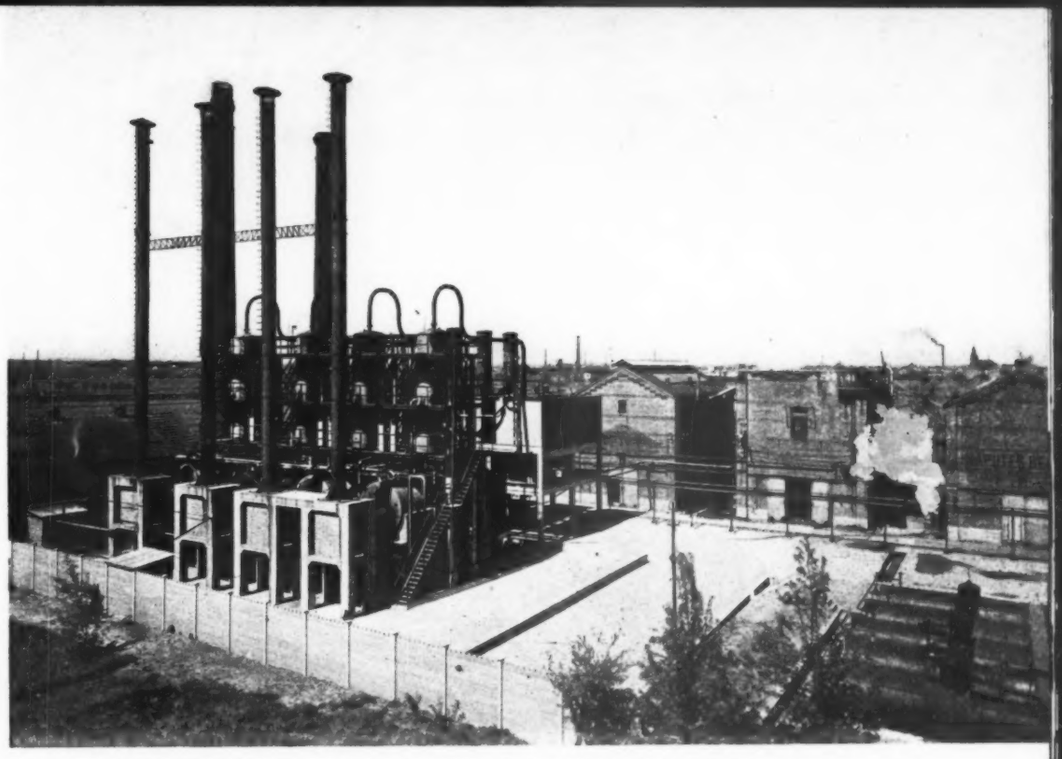
As 75 percent of Polish oil consists of paraffinic crudes deparaffining is one of the most important problems of the refinery. Both the heavy paraffine oils from the shell stills and that from the tower distillation presented difficulties in handling but these have been overcome by adoption of the de Laval centrifuge system, using trichloretane or bichloretane with benzene. This gives oil fractions of high quality and makes possible the production of automobile and aviation oils from paraffinic crudes. Except for the centrifuge, which was imported from Sweden, the plants were erected by Zeleniewski & Co., a Polish firm.

As part of its plan for national preparedness Sweden some time ago adopted a law requiring oil companies to carry larger stocks in storage. This has been followed up by a proposal for a government loan to Nordstjernan Rederiaktiebolaget of 6,000,000 kronen ($1,500,000) for the construction of a refinery of about 6,000 bbl. daily capacity at Nynashamn near Stockholm. The new refinery would contain cracking units and complete equipment for the production of gasoline, kerosene, Diesel oil, lubricating oil, fuel oil and asphalt. Its estimated cost is $2,500,000. A. Johnson & Co. the proprietors of Rederiaktiebolaget Nordstjernan, have stated their willingness, following the construction of this first plant, to erect another in western Sweden. Svensk-Engleska Mineralolje Aktiebolaget is increasing its storage equipment by the erection of tanks with a capacity of 17,500 metric tons.

Denmark is another country that is flirting with the idea of a government owned or government aided refinery but the project has not assumed definite form as yet.

The A/S Norsk Amerikansk Mineraloeljecompagni which operates a small refinery for the production of lubricating and transformer oils about 70 miles from Oslo is now planning the reconstruction and modernization of its crude batteries.

The outstanding addition to Britain's refining facilities during the year was the completion of the Manchester Refinery which was put into operation early in the year. The plant is described in full in another part of this issue. The other leading refineries in England have been enlarged and reequipped during the past two or three years so that few changes have been called for in 1938. One important improvement in prospect, however, is the remodeling and enlargement of the cracking equipment at the Fawley refinery of Agwi Petroleum Corporation Ltd. This will give increased capacity and greater flexibility in the refinery's operations.



Crude still in the refinery of the Compagnie Industrielle "Atlas" S. A. Belge.

After much discussion of a proposal for making the petroleum industry a state monopoly Portugal has entered into an agreement with "Redeventza" S.A. of Roumania by which the latter will undertake to build a plant near Lisbon on the River Tagus in consideration of an exclusive license to supply 50 percent of the country's requirements of finished products.

A new company, Sociedada Anonima Concessionaria de Refinicao de Petroleo em Portugal (SACOR) has been formed to build and operate the plant, one-third of the capital to be supplied by the government. The charter of the company is to run for 20 years with an option for extension under certain conditions. During the first half of this period it is to have exclusive rights to refine petroleum in Portugal.

The refinery will be designed to process crude oils of various kinds and to produce a full range of products, including aviation spirit, lubricating oils and asphalt. Details as to the equipment of the plant have not been released but an atmospheric and vacuum distillation unit having a capacity of 3,500 bbl. daily has been ordered. Contracts have been placed for necessary storage tanks and these will be erected by the end of the year.

Early in the year final shipments of machinery for the completion of the CEPSA refinery in the Canary Islands left the United States and it is understood that the refinery is now in full working order.

The greater part of the new refinery building to be done during the Third Piatiletka of the Soviet Union will take place outside of the Caucasus and this new building will follow the increases of crude production which are expected in the new eastern oil fields such as Emba, Bashkiria and others.

SOVIET REFINING

The design of the new refineries will follow either of two purposes: vacuum-atmospheric or atmospheric installations to process heavy and lubeoil base crude and combined installations for the processing of light crude with a view to obtaining gasoline of various grades for aviation, ordinary motor fuel and so on. All refineries will utilize gases.

Soviet refining equipment embraces 37 shell stills, 43 pipe stills, 23 lubeoil installations and six cracking installations or a total of 171 refining units for a total of 1,157,000 bbl. processing capacity per day.

Soviet Refining Facilities, October, 1938

Location	Stills					Capacity
	Shell	Pipe	Lubeoil	Cracking	Total	Bbl. Day
Baku	15	20	16	16	67	465,000
Batum	1	4	1	6	12	96,000
Grozni	7	9	3	24	43	373,000
Tuapse	1	2	—	2	5	52,000
Krasnodar	2	1	—	—	3	22,000
Makhatchkala	1	—	—	1	2	17,000
Konstantinovka	4	1	1	1	7	12,500
Yaroslavl	—	—	—	—	2	7,000
Santo Chimion	2	—	—	—	2	3,500
Neftdag&Vannovski	—	2	—	—	2	7,500
Saratov	—	—	—	10	10	38,000
Moscow	1	—	—	2	3	9,750
Orsk	—	1	—	2	3	17,500
Khabarovsk	—	—	—	1	1	3,000
Ufa	—	2	—	—	2	12,000
Odessa	1	—	—	1	2	5,800
Leningrad	1	1	—	—	2	1,750
Varinsk	1	—	—	—	1	5,700
Berdiansk	—	—	—	1	1	4,000
Kherson	—	—	—	1	1	4,000
	37	43	23	68	171	1,157,000

EGYPT

During the past year very important improvements and extensions to the Anglo-

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Egyptian Oilfields refinery have been decided upon. Owing to its comparatively isolated situation at the head of the Gulf of Suez, the refinery must of course be almost completely self contained. It is fortunate in having Nile water, supplied by canal, at its door for boiler purposes, while sea water is used for condensing and cooling. There is a fully equipped workshop and foundry, and the refinery produces all its own power from Diesel generators. Bulk shipments are dealt with from four berths, accommodating large tankers in a petroleum basin owned by the Egyptian government and situated within 1,000 yards of the refinery. Products are distributed both in bulk and packed, by arrangement with the Shell Co. of Egypt Ltd. Besides the drum factory, which has recently been largely extended to provide receptacles for benzine and gas oil as well as asphalt and lubricating oils, there is a large tin factory, producing normally about 5,000 tins per day.

Of the new developments the most important is the provision of a modern selective Dubbs cracking unit, 2,000 bbl. capacity, which is now in operation and provides not only a higher octane motor spirit, but also liquid butane. Treaters are being supplied for the products of this unit and in connection with its operation and the general expansion of refinery work the existing boiler plant is being replaced by modern water tube boilers and arrangements made to provide salt water for condensing and cooling at the rate of 1,100 tons per hour. Over 50,000 tons of new tankage capacity has been provided during the past year. Finally a new large and well equipped laboratory has been installed.

The production of Egyptian crude oil at present amounts to about 160,000 tons per year, and the refinery imports about 100,000 tons per year of crude oil plus the quantities of oil for asphalt manufacture previously mentioned. The quantities are actually processed in the refinery while other oils, amounting to nearly a million tons per year in all, are brought in for redistribution.

The refinery belonging to the Egyptian government, being originally built to deal with royalties in kind from Egyptian production, is naturally much smaller and is situated about a mile to the west of the Shell refinery. During recent years its operations have been considerably expanded and modern plant installed. A normal range of products is manufactured from crude oil distillation by tube still and asphalt is manufactured in a small vacuum unit. To augment their operations, in addition to the five percent royalty taken from Egyptian production, the government have during recent years purchased certain quantities, both of crude oil and of asphaltic residues, and their products are distributed chiefly for the use of government departments. The refinery is practically self contained, having its own power supply, workshops and laboratory.

There are hopes of increased production of crude oil in Egypt but in any case the oil refining industry at Suez has a very definite function and an undoubted future.

NEAR EAST

Contributing importantly to the expansion of refining facilities in the Near East will be the plant of Consolidated Refineries Ltd. at Haifa, Palestine. It is reported that preliminary work on the site already has begun, that contract for the constructional work has been awarded to M. W. Kellogg & Co., that the work of erection will begin very shortly and that completion of the plant, barring unforseen delays, is set for late in 1940.

Consolidated Refineries Ltd. is a joint enterprise of Anglo-Iranian Oil Company, Ltd. and the Royal Dutch Shell group. The crude supply of the refinery will be drawn from the respective shares of the two interests in oil from Kirkuk delivered at the Haifa terminal of the Iraq pipeline.

The completed plant will have a capacity of roundly 2,000,000 tons annually (roughly 40,000 bbl. per day). It will include full topping and cracking equipment for the production of all grades of motor spirit, gas oils, Diesel oils and bunker fuel. An Edeleanu plant will be provided for the treatment of kerosene. The refinery will be electrically operated with power supplied partly from the company's own station and partly from the Palestine Electric Corporation's plant at Haifa. In laying out the surroundings of the plant special attention will be given to the provision of canteens, changing rooms, bath houses and recreation grounds for the comfort and welfare of employes.

In the annual report of Anglo-Iranian Oil Company, Ltd. the Chairman referred to the development of new fields in southern Iran and stated that if production in this area confirmed early prospects it might lead the company to establish a new refinery somewhere in the vicinity of Bandar Shapur to handle this crude. While this project belongs definitely in the future it is altogether probable that a plant will be constructed in this general location as production develops.

In order to handle the growing output of crude from the Dhulian field and to provide the range of products required by its markets the Attock Oil Company Ltd. has decided to reconstruct its refinery at Rawlpindi, India, raising its capacity from the present 1,500 bbl. to 4,000 bbl. daily. To supply crude for the enlarged plant a 51-mile, 6-inch pipeline will be built.

Features of the refinery will be a Lummus atmospheric vacuum unit handling 900 bbl.

Flexibility Characterizes Recently Completed

MANCHESTER REFINERY

Above, view of outside Borsig boilers and Edeleanu building: below, process control laboratory.

Centered in Britain's Richest Lubricating Oil Market, with Direct Access to Ocean Tankers and Well Located in Case of Emergency: Manchester Plant Now Operating Satisfactorily.

MANCHESTER Oil Refinery, Ltd., was formed in December, 1936, with the object of erecting at Trafford Park, Manchester, a refinery possessing the latest technical equipment for the production of high-class solvent treated and dewaxed lubricating, transformer and white oils, conventionally treated lubricating oils and the following by-products: kerosene, gas oil, Diesel oil, fuel oil, axle oil and dark cylinder stock.

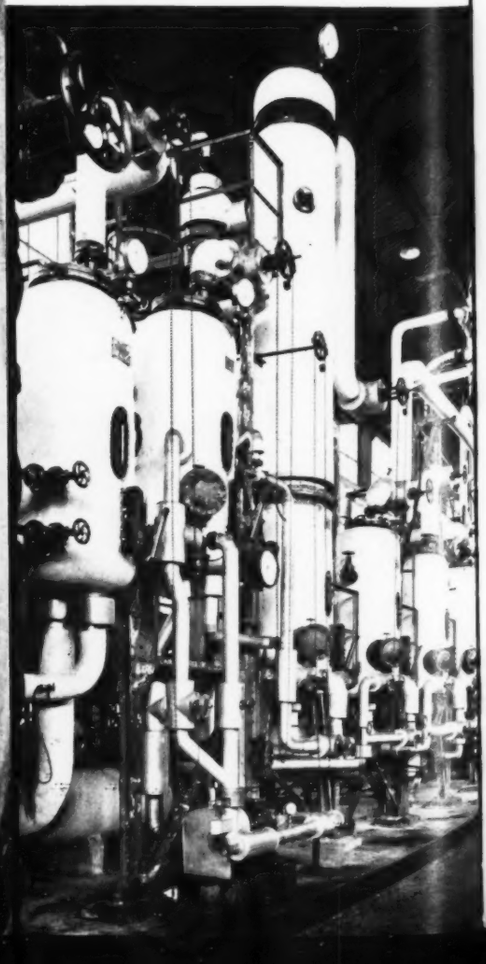
Manchester was chosen as the site for the refinery for the following reasons: because consumers of 40 percent of the British total of lubricating oil and of 65 percent of the British total of transformer oil are within a radius of 100 miles of Trafford Park.

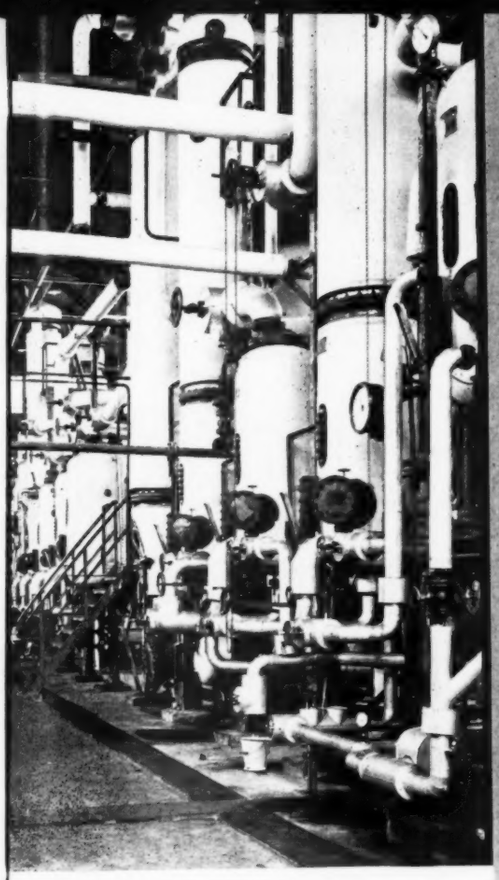
The refinery, by reason of its situation on the Manchester Ship Canal, has also the advantage of direct access to ocean tankers, and is, therefore, in a particularly favorable freight position for overseas cargoes. Moreover, the western coast must be considered as the safest in times of emergency.

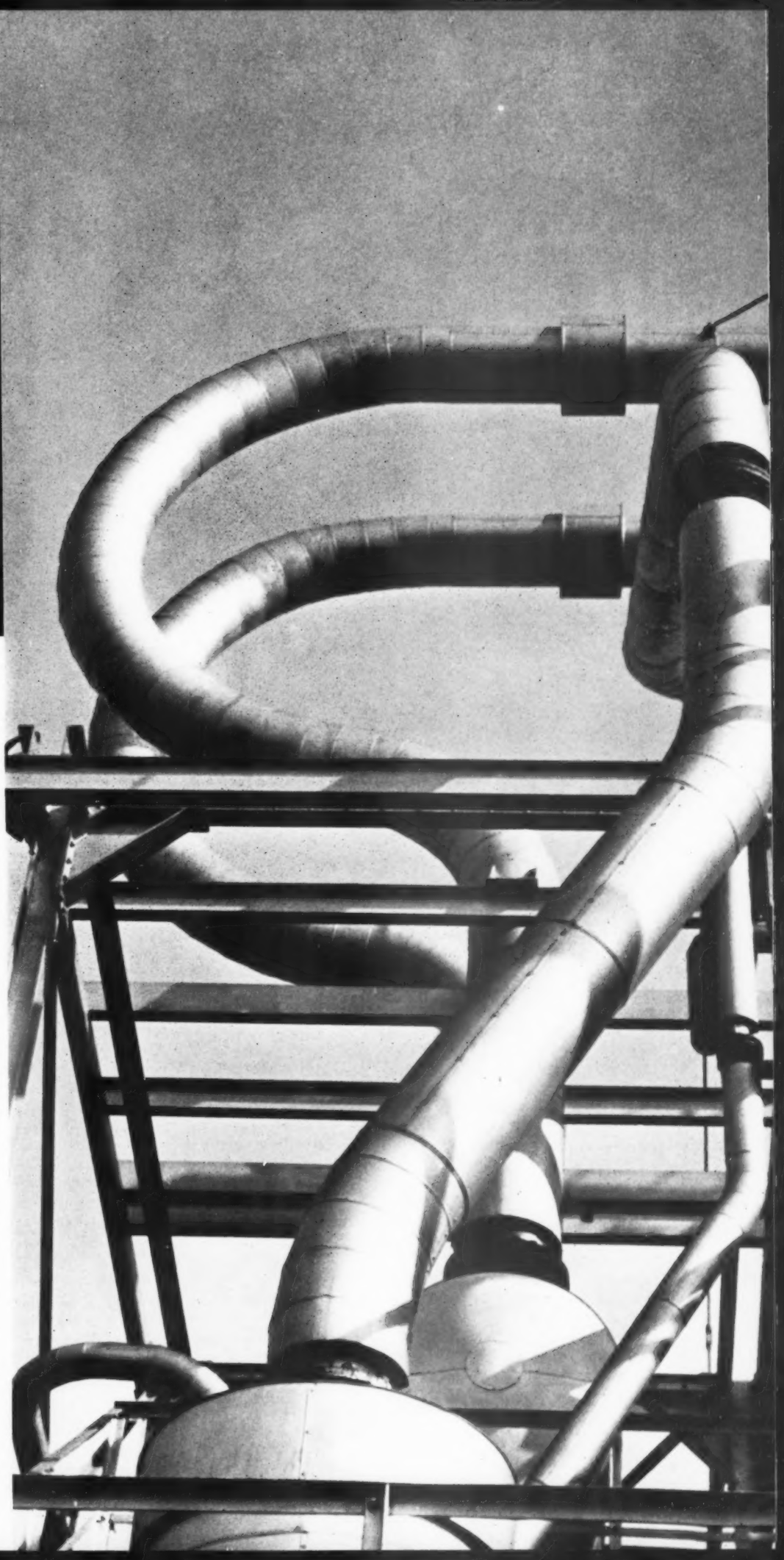
Manchester Oil Refinery, Ltd., is an entirely independent British company. It has an authorized share capital of 400,000 5½ percent convertible and redeemable cumulative preference shares of 5s. each, 880,000 "A" ordinary shares of 5s. each and 80,000 "B" ordinary shares of 1s. each, making a total capital of £324,000, of which £305,575 10s. is paid up. The "A" and "B" ordinary shares rank alike except as to voting.

The board of the company consists of

Left: storage tanks at the Manchester refinery. Below: general view of extraction units, Edeleanu plant.







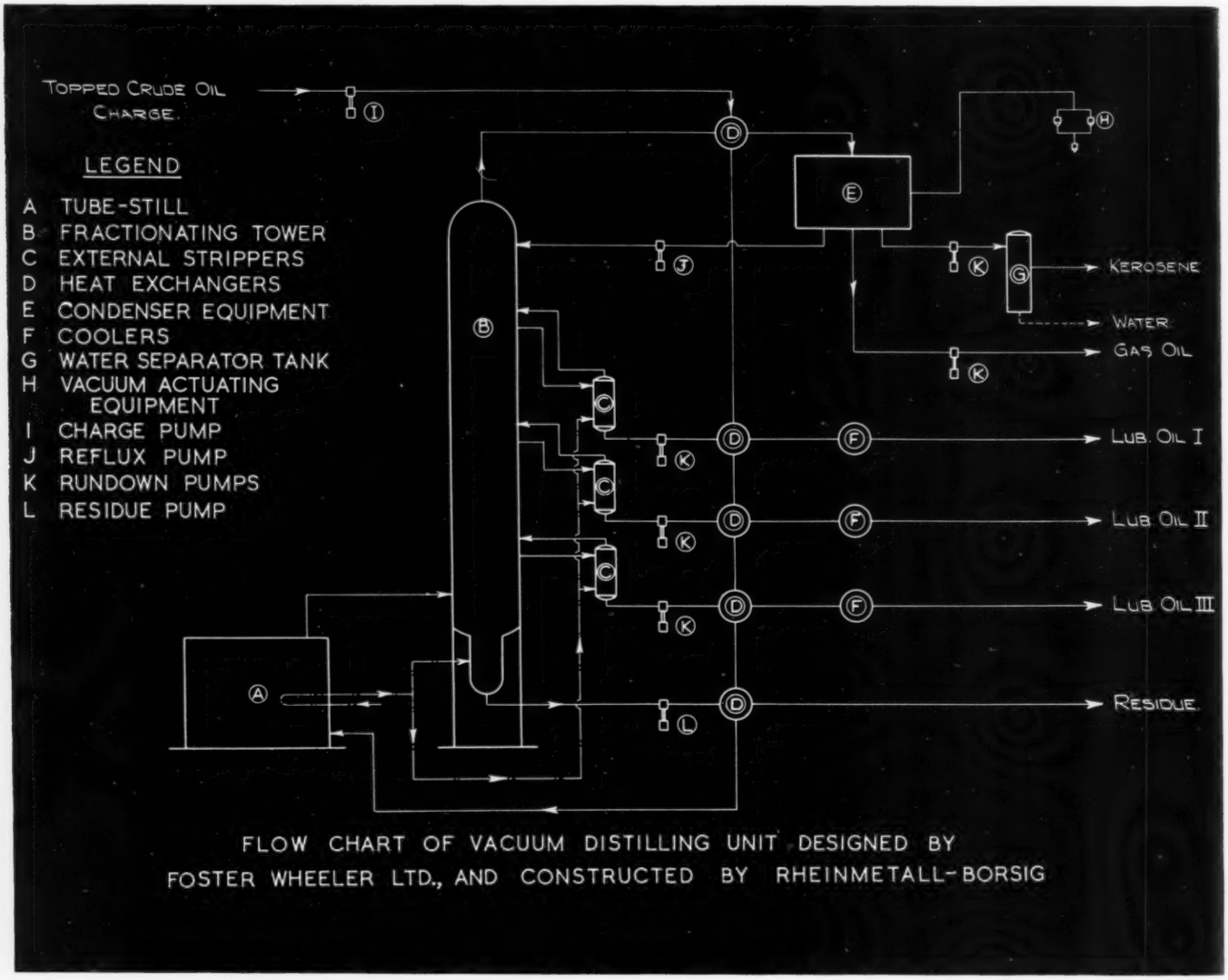
Above: extraction units in the Edeleanu plant. Right: part of the distillation unit.

Major A. G. Church, D.S.O., M.C., J. M. F. Cohen, H. Stuart Ebben, G. Tugendhat, L. H. Watts. Dr. F. Kind is the managing director. E. J. Dunstan, M.Sc., M.Inst.P.T., has been appointed manager of the refinery.

The refinery comprises a high vacuum distillation unit, with a capacity of 150,000 tons per annum; the latest type of combined solvent treating and dewaxing benzol-SO_2 (Edeleanu) plant, with a yearly capacity of 40,000 tons; a De Laval acid treating plant, and a contact clay treating and filtration plant, with an annual capacity of 60,000 tons; storage tanks of approximately 30,000 tons capacity; boiler plant and complete auxiliary equipment.

The refinery is constructed to work either topped crudes or natural crudes containing a little gasoline, in order to comply with the regulations of the Manchester Ship Canal, which do not permit the transport in large vessels of any material with a flash point below 73 deg. F.

It is the intention of Manchester Oil Refinery to act as an independent refinery, working to the highest standards; to select suitable crudes for the purpose of producing as economically as possible highest quality products, and to distribute these products through existing organizations to the trade. Although British and Dominion markets are considered as the chief outlet for the company's products, some specialties may be exported to the Continent and to overseas markets.



FLOW CHART OF VACUUM DISTILLING UNIT DESIGNED BY FOSTER WHEELER LTD., AND CONSTRUCTED BY RHEINMETALL-BORSIG

Orders for the construction of the plant were placed at the beginning of 1937; construction work started in the summer of 1937; and the distillation plant started operating at the beginning of April and the solvent plant at the beginning of May, 1938. The refinery was designed and constructed under the supervision of Harold Moore, M.Sc.(Tech.), M.Inst.P.T., A.Inst.Mech.E., of Moore and Geore, Ltd.

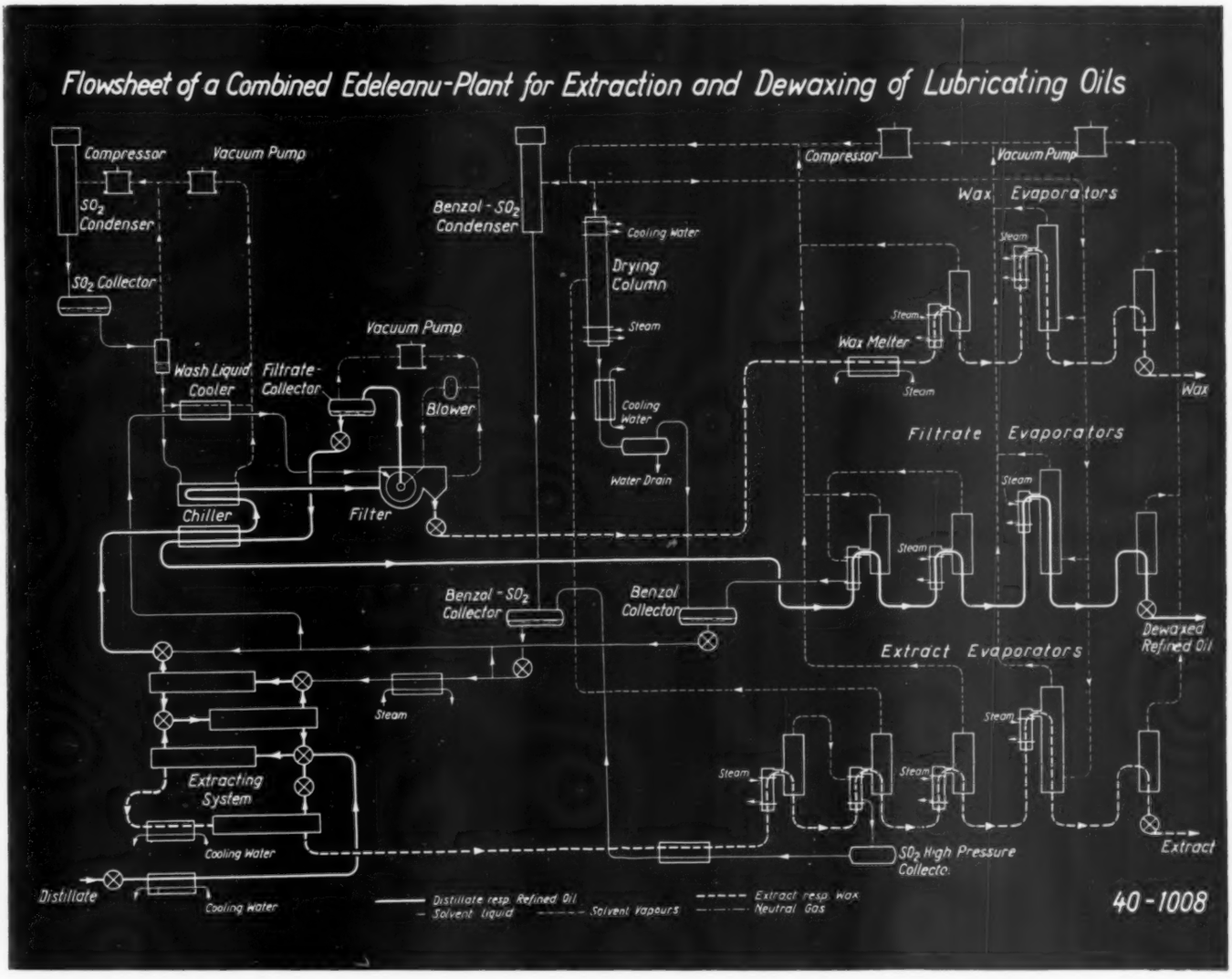
Through the company's managing director, Dr. F. Kind, friendly relations are assured with the Antwerp refinery of "Redeventza" Belge and the Trieste refinery of "Aquila" S.A. (which are also under the management of Dr. Kind). Manchester Oil Refinery has thus the benefit of the experience of these two companies.

The Foster Wheeler distilling unit was designed with a very exceptional degree of flexibility. It is capable of handling residue produced by the topping of the large number of crude oils available in the open market, and it can also distill heavy crude oil containing less than five percent boiling up to 230 deg. C.

As shown on the accompanying flow diagram, the unit was designed to secure essentially an overhead kerosene and gas oil producing three lubricating oil fractions and a residue. Naturally, yields of these fractions from different reduced crudes vary considerably, and the side stream equipment was designed after a wide survey of possible charging stocks of adequate size to handle any of the variations which might be encountered.

The unit was designed for a specified nominal capacity of 2,000 bbl. per day, and owing to the different percentages of vaporization which would be required with different charging stocks a high degree of flexibility was also essential in the tube still and fractionating tower. On certain charging stocks, therefore, the unit is capable of considerable overload capacity, and up to the present it has been operated on throughputs as high as 2,700 bbl. per day.

It was contemplated that the charging stocks supplied to the unit would generally have as a lightest component a fraction more or less of the heavy gas-oil type, representing the ordinary run of residue from an atmospheric distilling unit. On the other hand, it was also appreciated that the degree of stripping of the topped crude or fractionation between the initial components of the topped crude and the lowest side stream of the topping unit would vary from one charging stock to another, depending upon whether the unit in which the topping operaion was carried out was of a modern efficient type or effected only a rough skimming operation. In the latter event, and also when charging untreated heavy crude oil, the crude might contain, through insufficient stripping, some light ends with a boiling range much lower than that of the usual heavy gas oil initial fraction, these being possibly more of a kerosene character. In the designs, provision was accordingly made for condensing such light fractions.



This is effected by means of a stepwise condensation which brings down the lightest fractions in the presence of the process steam, the usual barometric condenser for the latter being omitted. In this way the overhead distillate product can be secured in two fractions, one heavy and the other a light fraction. No attempt is made to fractionate these cuts properly, and any kerosene present in the lighter stream naturally contains gas oil, while the gas oil in the heavier stream contains kerosene.

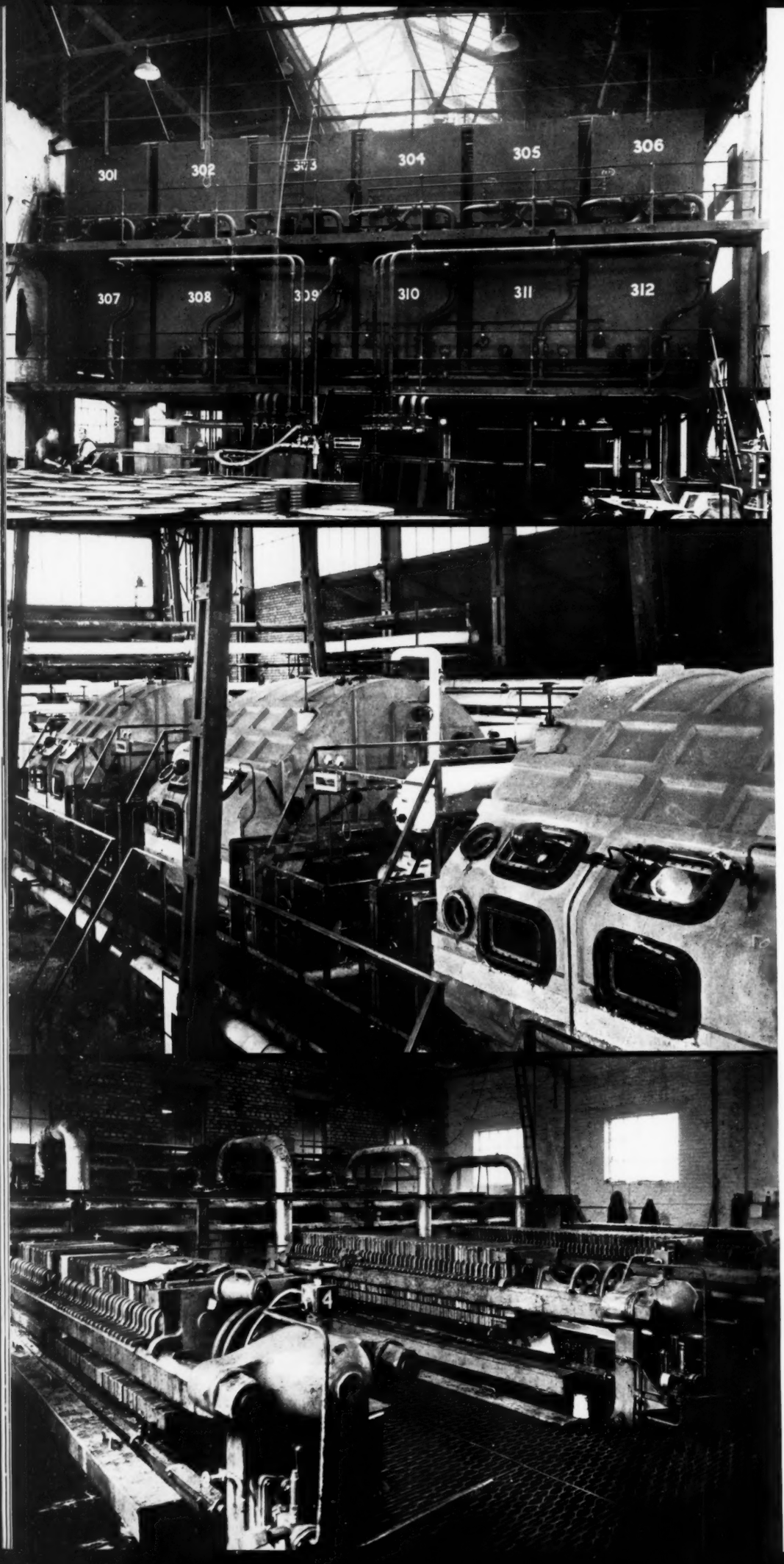
The method of operation is the single flash system utilizing one tube still and one vacuum fractionating tower. The charge is picked up by a pump from the storage pipeline at the unit, and delivered through heat exchangers located on the overhead vapor product from the top of the tower, on all the side stream products and on the residue product, in which it is preheated before passing under pressure to the tube still.

In the tube still it is heated by convection and radiant heat to the required temperature for the necessary vaporization. The charge is then flashed directly into the vacuum fractionating tower which operates under vacuum, produced by means of steam jet air pumps.

The combined overhead vapor product of kerosene (if present) and gas oil is secured from the top of the tower and is partially condensed and cooled in a vapor heat exchanger and vapor condenser, from which the condensate flows to a rundown tank and thence a part is pumped as liquid reflux to the top of the tower, while the balance, consisting of the net yield of gas oil, is pumped to storage. The lighter vapors of kerosene and process steam pass via a vapor line through a second condenser and are collected in a rundown tank. From this rundown tank the kerosene and water are pumped to a water separator from which the kerosene flows by gravity to storage. A vapor line from the rundown tank delivers air and uncondensable gases to the suction of the steam jet air pumps, which maintain the necessary vacuum within the condensers and fractionating tower.

The lubricating oil fractions are secured as liquid side streams, each flowing by gravity from one of two alternative offtakes incorporated to provide flexibility of fractionation. From the tower each of these products passes to an external stripper in which it is subjected to stripping by means of steam which has been superheated by elements located in the tube still setting. The stripping steam and light vapors from each stripping sectio.1 are vented back to the tower, and each product is pumped from its respective external stripper through a heat exchanger and cooler to storage. The residue is pumped from the base of the tower through a heat exchanger to storage.

In general this unit is similar to the vacuum stage of the Foster Wheeler predistilling atmospheric and vacuum distilling unit recently built for "Aquila" S.A. at Trieste, the only modification being overhead condensing arrangement. The "Aquila" unit



has proved very successful in operation on a wide range of crude oils, and it is interesting to note that within six days of starting up, the vacuum distilling unit at Manchester was in operation under high overload conditions, and within six weeks of starting it handled two different types of topped crude and one natural crude. As in the case of the unit at Trieste, this unit was constructed by Messrs. Rheinmetall-Borsig A.G.

For the solvent dewaxing plant the benzol-SO_2 process, which is generally known as the Edeleanu process, was chosen because the same chemicals, namely benzol and SO_2, act both as selective solvents and as media for dewaxing. It is an essential advantage of this plant that the same solvents can be used for both operations, so that the separation of solvent between the extraction plant and the dewaxing plant, which is necessary with all other processes, can be avoided. The application of two solvents further makes it possible to vary the selectivity of the solvent, not only according to quantity of solvent and temperature, but also through changing the proportion in which benzol and SO_2 are used. In addition, the boiling point of both solvents is so low, and differs so much from the boiling points of the oils that are treated, that the separation is easily possible without any fear of overheating the treated oil or of decomposing the solvents. Therefore it is possible to treat in the solvent plant not only lubricating oils, but also gas oils, and if necessary kerosene, thus increasing its flexibility. Both solvents are easily obtainable in England at comparatively low prices.

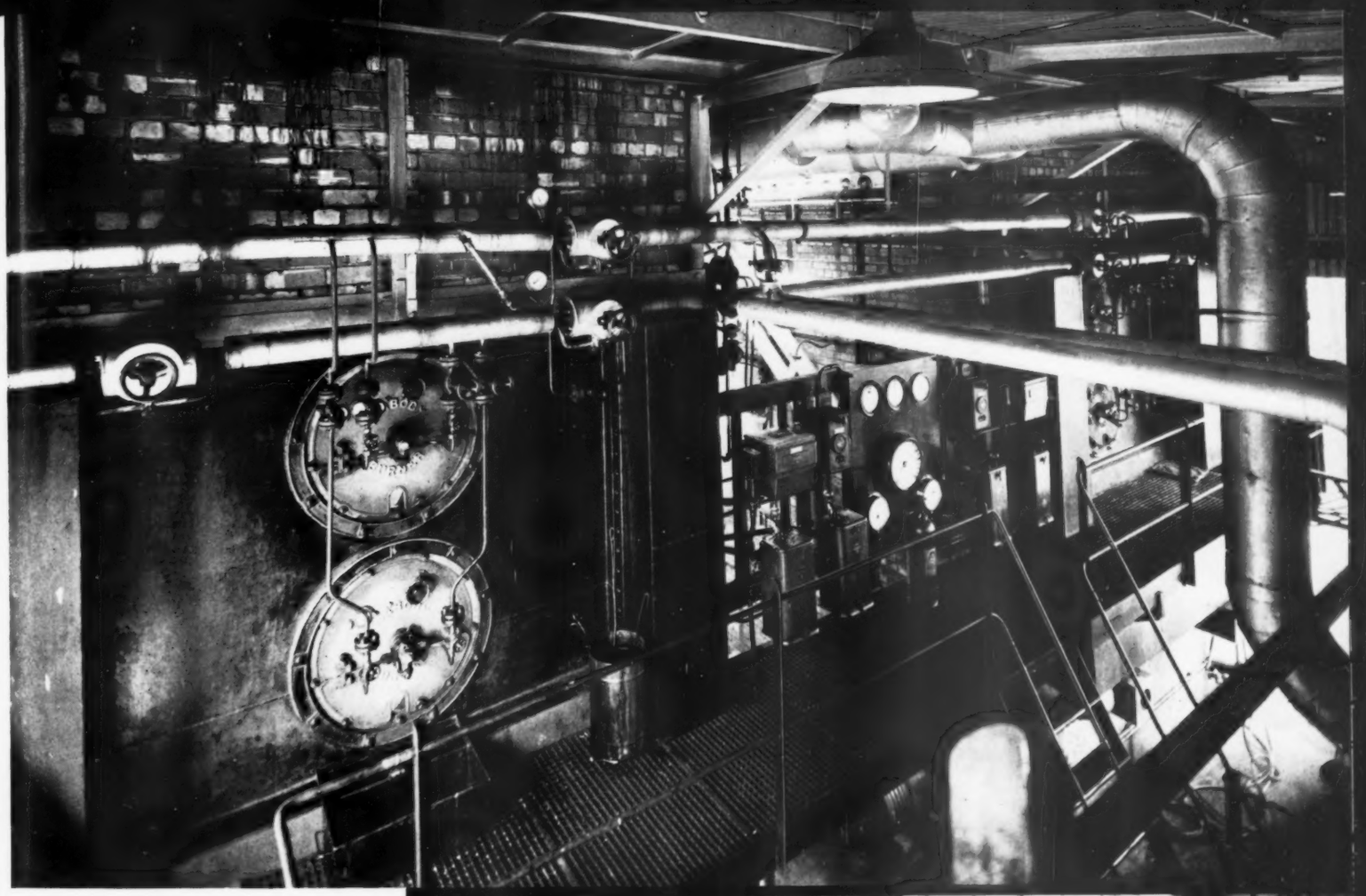
In designing the combined Edeleanu plant for Manchester Oil Refinery, Ltd., improvements resulting from experience with similar plants were incorporated. For instance, it was designed in such a way that it will be possible either to dewax or extract the oils according to the varying demands of the market.

The scope of the plant can be further enlarged by changing the working conditions; for instance, the composition of the solvent mixture, the ratio of solvent to oil, or the treating temperatures. The process can thus be adapted to varying qualities of distillates or finished products.

A detailed description of the plant follows, and it will be easier to understand this if reference is made to the accompanying flow sheet.

The distillate first enters the extraction plant where it is counter-currently treated with a 25 : 75 benzol-SO_2 mixture. By this process it is divided into two layers; the

Top: blending and filling facilities of Manchester refinery. Centre: rotary filters, Edeleanu plant. Bottom: filter press platform.



Above: firing and control platform and boilers. Right: chillers, Edeleanu plant.

raffinate and the extract solutions, which differ in their specific gravities. The extract solution, containing the heavier hydrocarbons and the larger part of the solvent, forms the lower layer of the two-phase system. It contains all the compounds undesired in lubricating oils, i.e. the components which are liable to oxidation and cause sludge formation as well as ring sticking in motors.

The system employed to indicate the relative positions of raffinate and extract is worthy of mention. The higher conductivity of the extract is used through the medium of neon lights, and a series of conductors is placed at different depths in each mixing vessel; each being connected with a light mounted on a special panel.

After passing a preheater the extract solution is freed from the solvent in the extract evaporators under decreasing pressures and is then withdrawn. It may be mentioned here that the extract obtained by the Edeleanu process can be made use of, for example, as fuel oil, or for cracking purposes.

Furthermore, the extract, containing as it does the most chemically reactive compounds in the oil, must surely prove even-

Left: boiler plant at Manchester refinery.

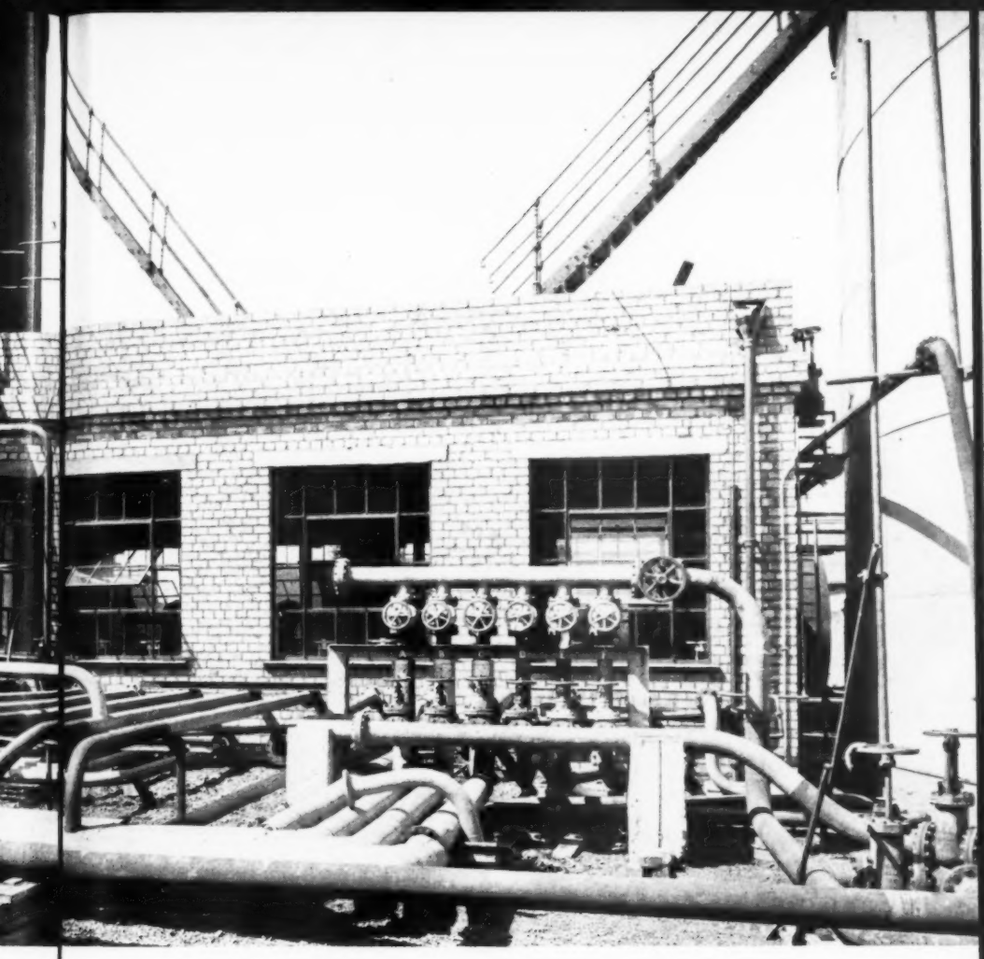
tually of considerable interest as a subject for chemical processing, or for use as high pressure lubricant.

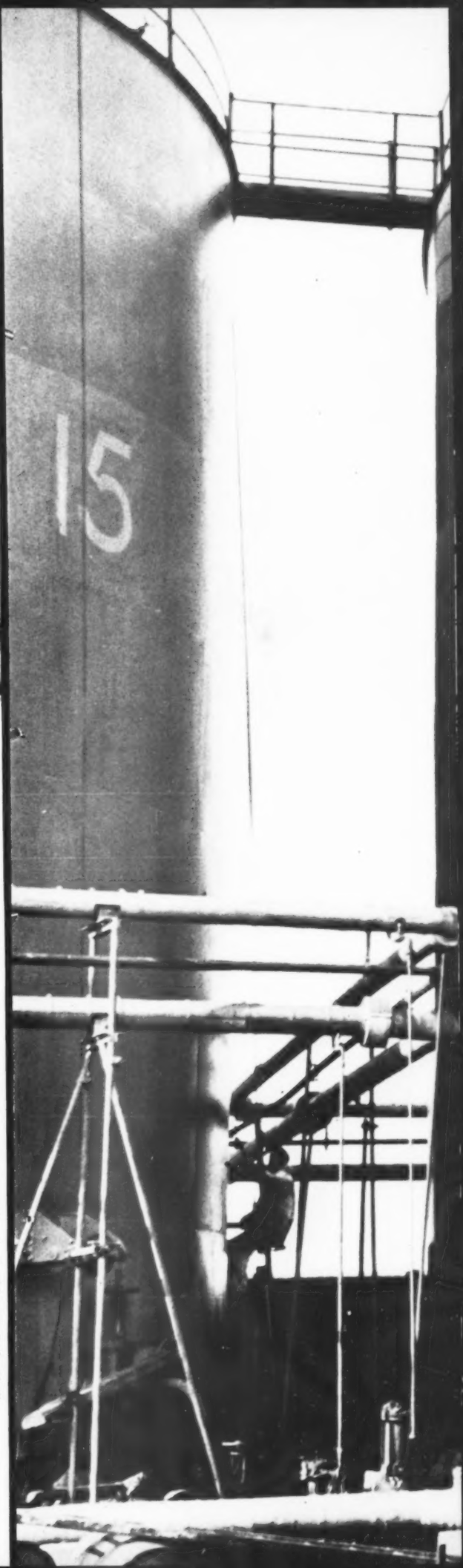
The raffinate contains the wax and the paraffinic saturated hydrocarbons. These are particularly resistant to oxidation and possess the desired oiliness and viscosity temperature characteristics. The raffinate solution, containing only a small part of the solvent is further diluted, the benzol-SO_2 ratio being reversed to approximately 80 : 20. The solution thus obtained passes to the chillers.

Precooling is effected by the filtrate passing from the filtrate collector to the evaporation system, and in the process the filtrate itself obtains a preliminary heating.

It will be seen from the flow diagram that a special cooling system is provided for the dewaxing plant. The necessary low temperatures are obtained by evaporation and compression of SO_2. The cooling temperature required is only 5 deg. to 10 deg. F. below the pour point of the oil.

The cooled solvent-oil mixture is led to the rotating filter drums. The filter cake is washed with solvent previously chilled in a special cooler. After a suction period for the removal of the washing liquid the filter cake is blown off by means of a neutral gas.





Above: Manifold transfer pump house. Right: painting tanks of the storage installation.

It is then pumped to the wax melter and thence to the steamheated wax evaporators where any remaining parts of the solvent are removed.

The dewaxed raffinate (filtrate) is pumped to the filtrate evaporators where it is freed from the solvent under decreasing pressures, the last traces of benzol being stripped by SO_2 under vacuum.

It is an interesting feature of the plant that the second extract evaporator and the first filtrate evaporator are not provided with a steam-heating device; instead, vapors from the adjoining steam-heated evaporator are used for heating. By this process, the heat content of part of the solvent vapors is used in a most economical manner for driving off the SO_2 in the neighbouring evaporator, the solvent vapors being simultaneously condensed.

Another noteworthy item concerns the working of the drying column. Though the distillates contain only very small amounts of water, a gradually increasing water content of the solvent is not entirely avoidable. It was found that it suffices to dry a portion of the sulphur dioxide, which is preferably withdrawn from the second extract evaporator. The functioning of the drying column in the centre of the flow diagram (the column is constructed of stainless steel to resist corrosion) is dependent on a heating system based on the thermosyphon principle situated at the base of the column.

In order to reduce the load on the compressor, the SO_2 used for stripping is obtained by means of a rectifying column.

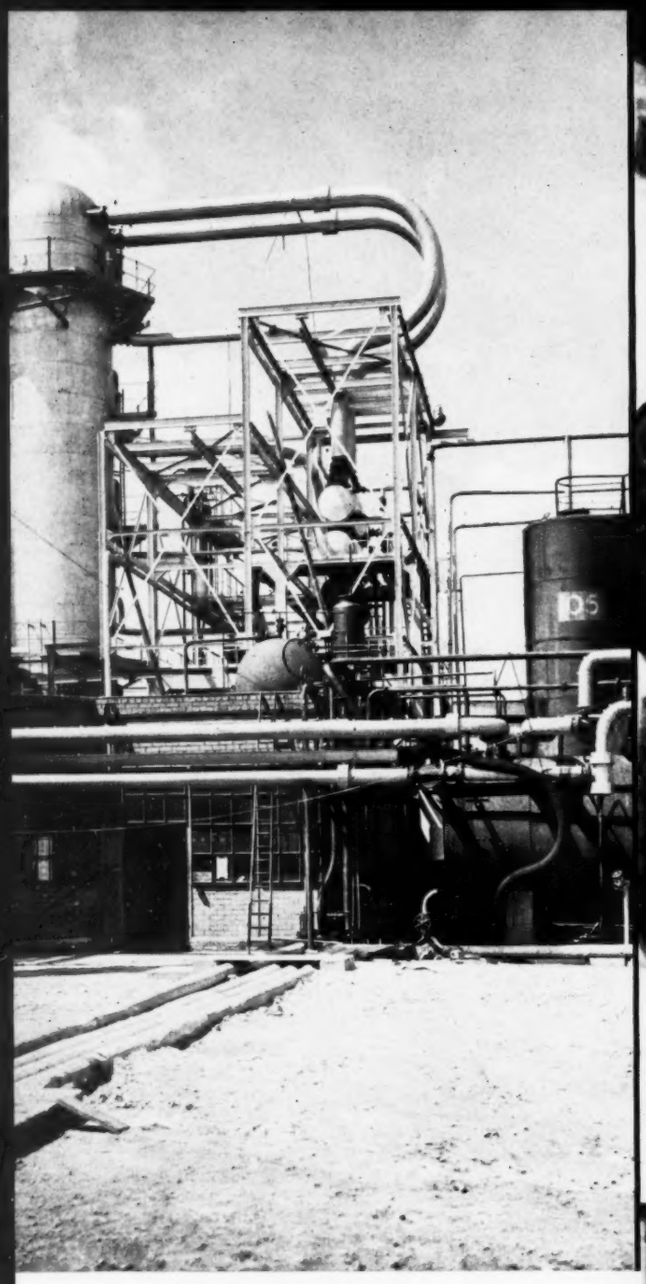
Economy of the services has been studied throughout the design, and heat exchange is employed wherever possible to minimize demands on steam and water.

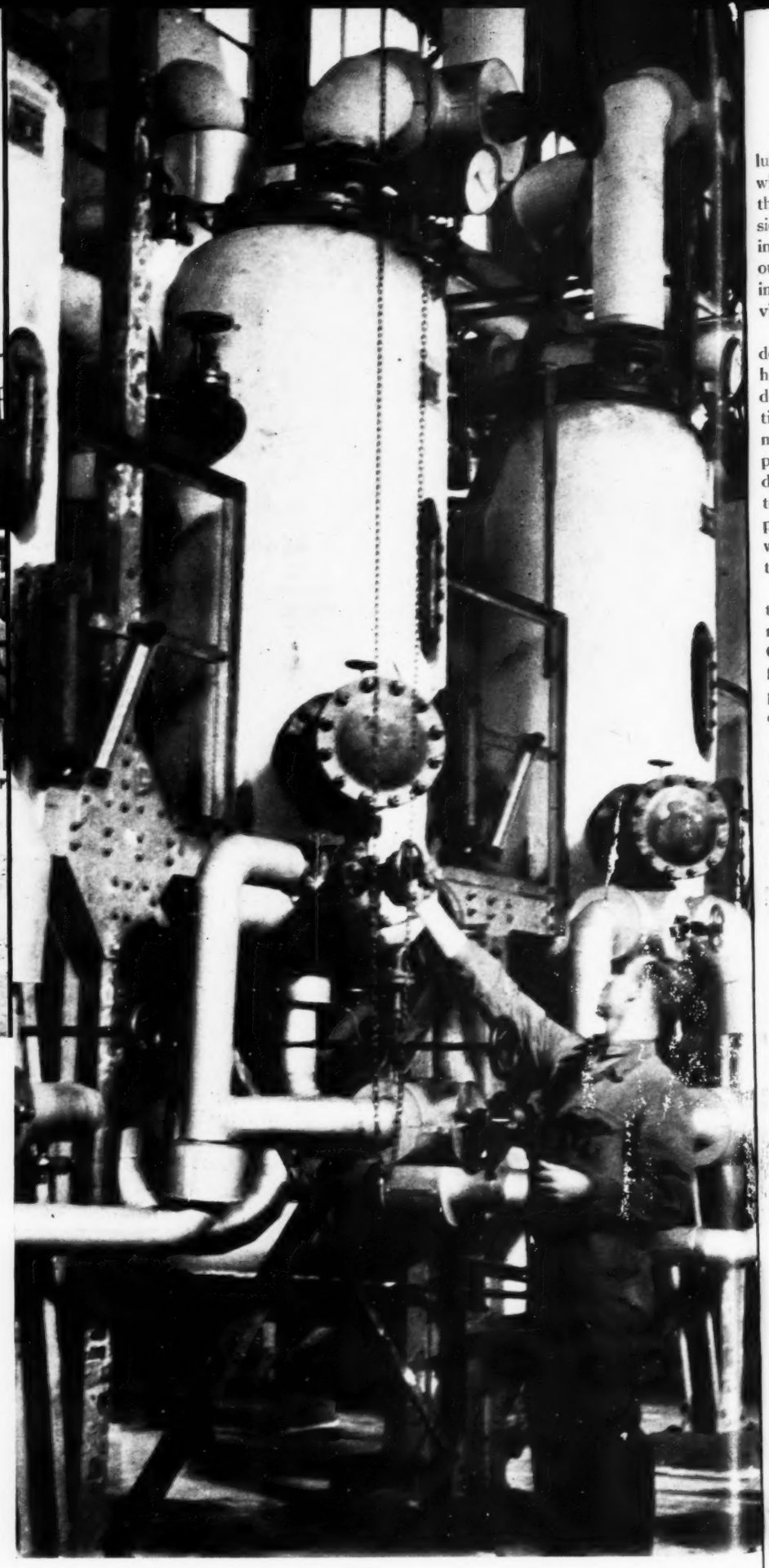
The following are typical analyses of the products of this plant:

Typical Analysis of Products from the Solvent Extracting and Dewaxing Plant

	Transformer oil	"Solmor" B	"Solmor" C
Specific gravity at 60°F.	.830	.866	.881
Flash point: closed °F.	315	410	445
open °F.	340	435	480
Viscosity Redwood at—			
60°F.	70 secs.	—	—
70°F.	—	845	899
100°F.	—	122	343
140°F.	—	63	139
200°F.	—	42	56.5
210°F.	—	39	53
Viscosity index	—	130	114
Pour point °F.	—0	5	10
Color	—	1½ ASTM	—2 ASTM

The boiler plant, also supplied by Rheinmetall-Borsig A.G., consists of two boilers each of 12 tons capacity operating at a steam pressure of 300 lbs. The boilers are of water tube type, oil fired, with forced draught, and are of the outdoor type, no boiler house being employed. If necessary coal firing can easily be installed. The steam is reduced from 300 to 150 lbs. pressure





Foster Wheeler distillation plant—right, changing flow valve in Edeleanu plant.

through three turbines, which are directly coupled to centrifugal pumps, which in turn supply the cooling water for the various units. All the pumps in the vacuum distillation plant, as well as the clay mixers, are supplied with steam at 150 lbs. pressure and exhaust at a pressure of 20 lbs., the low pressure steam being used as process steam and for tank heating. The steam pressure for the different processes is automatically controlled to all parts of the refinery through the medium of Panta regulators. A very exact control of steam pressure has been attained, which reflects favorably on the smoothness of operation experienced in the various processes.

The chemical treatment plant is divided into two sections: one consists of acid treatment and the other of absorbent clay treatment.

The continuous acid refining plant for lubricating oil has been built in accordance with the De Laval S-N system. It comprises three entirely separate treating units (provision has been made for a fourth unit to be installed at a later date), each having an output of 1½ to 3 tons per hour of lubricating oil, depending upon the grade and viscosity of the oil handled.

Each unit incorporates a proportionating device for concentrated sulpuric acid; a heat exchanger; and a proportionating device for raw oil. Oil and acid are continuously mixed in a high-speed centrifugal mixing pump, and the treated product passes to a reaction tank which allows the desired reaction time between acid and oil to be effected. The acid-oil mixture then passes to the De Laval S-N centrifuge, where complete separation is effected between oil, acid sludge and free acid.

The treated oil is run to intermediate tanks, from which it is pumped to clay mixers operating on the batch system. Clay is removed in a system consisting of four filter presses, and the finished oil is passed to rundown tanks. The process is controlled at all stages by the laboratory.

All oil constant level tanks are fitted with Electroflo temperature recorders, while the system used for the most viscous oil is fitted with an automatic temperature controller. The necessity for very exact control on viscous oils is great, as a fine line has to be drawn between the minimum temperature required to give fluidity and the maximum temperature not to be exceeded to avoid too harsh a reaction.

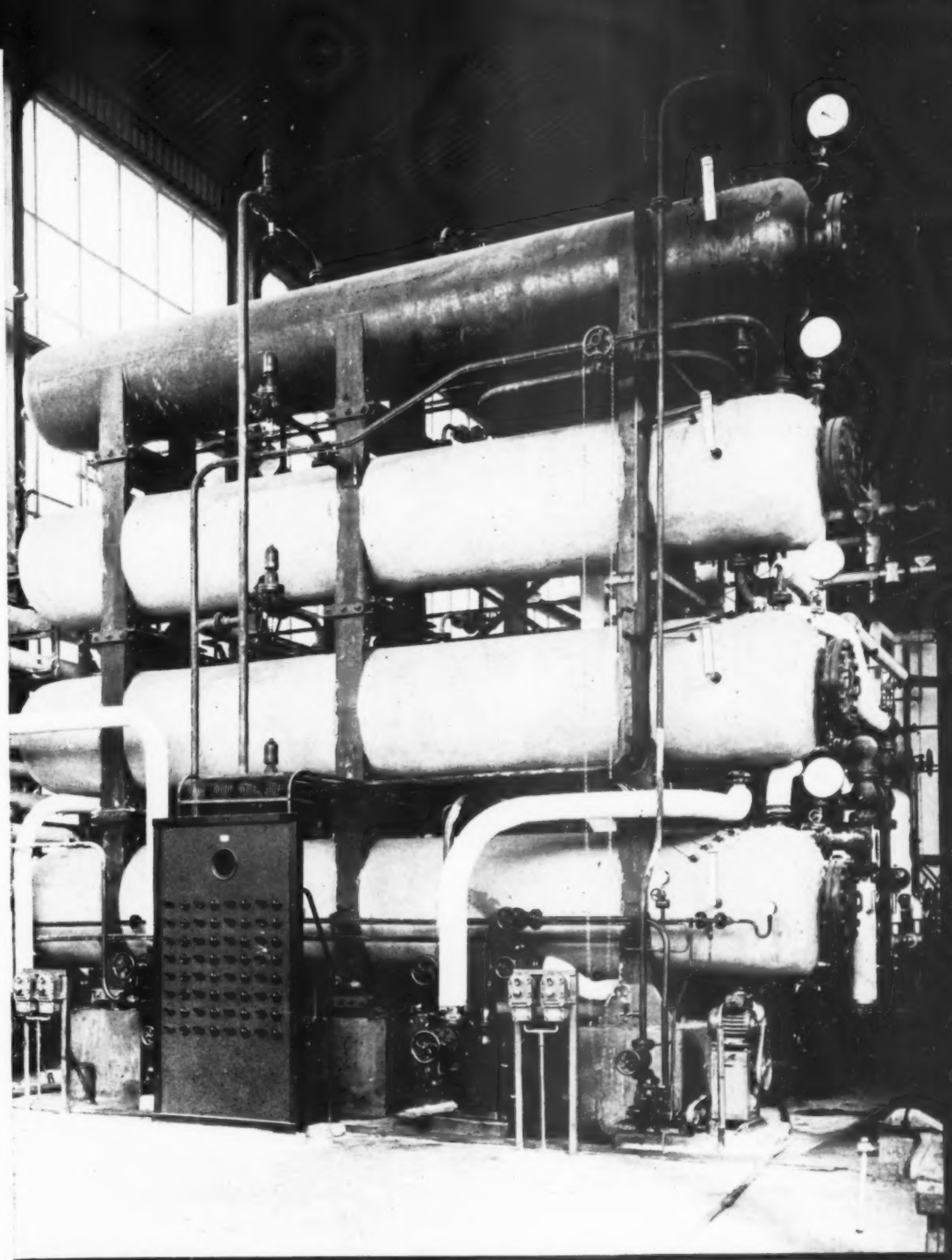
Control of the product from the centrifuges is made continually, to ensure maximum throughput and maximum desludging simultaneously.

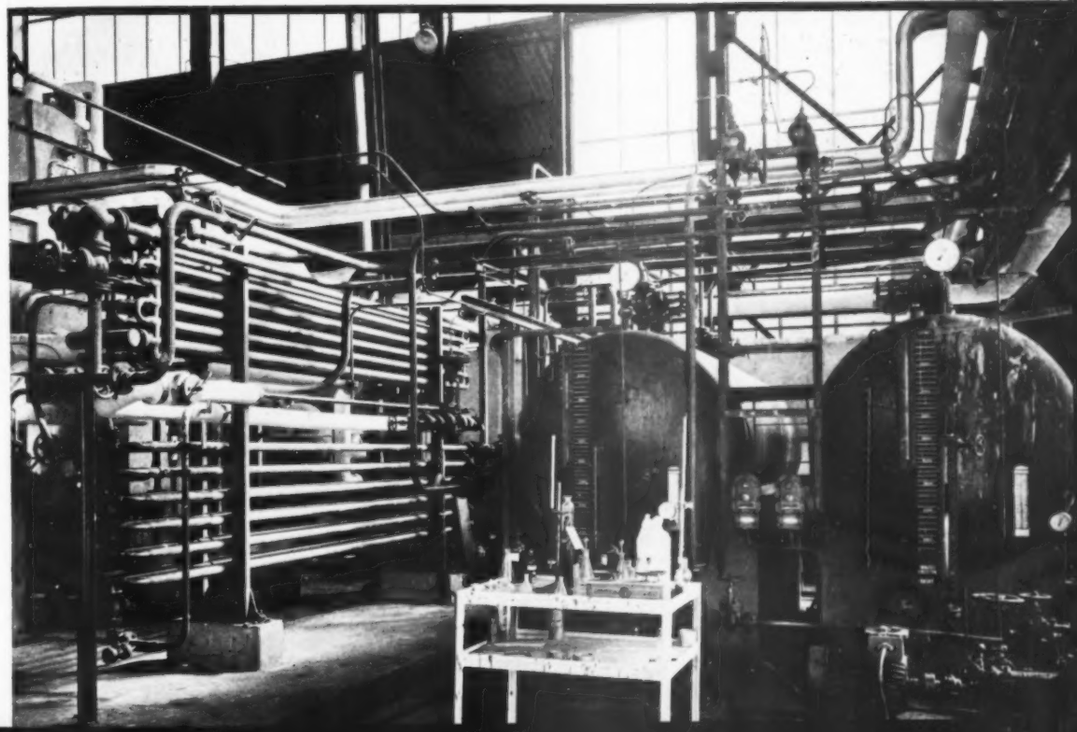
The treated oil is run to intermediate rundown tanks, where batches are accumulated large enough to charge the clay mixers.

The clay mixers, four in number, are of the conventional batch type, heavily coiled to give quick heating to the charge. The activated clay is added through an air blast system which transports it from a small feed tank situated in the clay store, through a pipeline to the contacting vessel.

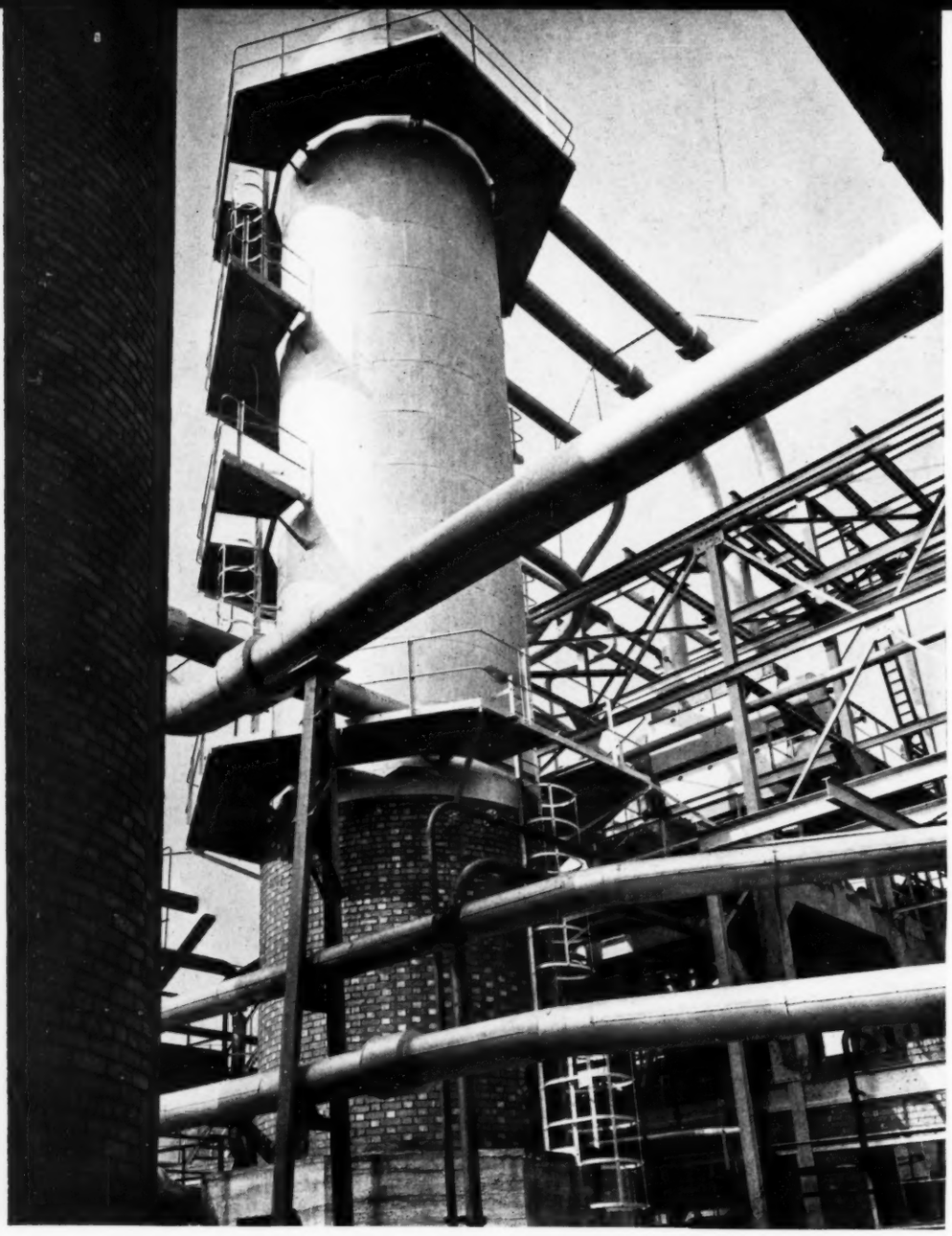
Two methods of mixing are employed simultaneously, namely compressed air and pump circulation. Very efficient contact is obtained in the system, leading to economies in clay.

The clay is removed from the oil in a system consisting of four steam heated filter presses, from which the finished oil passes to four rundown tanks. The spent





Edeleanu plant—top, reaction vessels; bottom, benzole storage tanks.



Foster Wheeler fractionating column, Manchester refinery.

clay falls directly through chutes into skips.

The fact that the treating plant has been installed in three separate units renders it possible to handle three different grades of oil at one time, or alternatively of course, one grade of oil can be passed through the three units.

Extreme flexibility of operation is claimed for this modern treating system as well as accurate control of treating conditions. At the same time a saving in acid is effected due to very efficient contacting, and a saving in oil due to the greater efficiency of centrifugal separation as compared with gravity settling.

The laboratory is fully equipped in every detail and full investigations in the products can be carried out. Provision is also made to enable the more important American and Continental tests to be carried out.

Owing to the specialized nature of some of the products, such as transformer oils, and oxidation resisting lubricants, special equipment has been provided such as a sludge testing apparatus and oxidation test equipment.

The routine laboratory controls the products during each stage of manufacture.

Direct pipelines connect the refinery with the jetty at Barton, where sea-going oil tankers can load and discharge. There are also facilities for loading barges on the Bridgewater Canal, which connects the refinery with the whole of the British canal system, by means of which oil can be taken as far as London, Birmingham, Leeds and Hull.

The blending shed is of ample capacity, and has two special continuous clarifying systems, designed by Moore & George, Ltd., by which the oil is blended and heated up to 250 deg. F., then flashed in a high vacuum drum to remove the last traces of moisture. This procedure ensures a thorough mixing of the blend components.

In addition to the tanks previously existing on this property, a considerable amount of additional tankage was required and the order for 12 new vertical cylindrical tanks was placed with The Whessoe Foundry and Engineering Company, Ltd., of Darlington.

There are five tanks of 1,500 tons and five others of over 1,000 tons capacity each. One larger tank of 59 ft. diameter and 38 ft. 6 in. deep and one smaller tank of 19 ft. diameter and 26 ft. deep complete the 12.

In addition, Whessoe carried out complete renewal of the roof sheeting of the existing tanks, two of which are 50 ft. in diameter, one 77 ft. diameter and a fourth 17 ft. diameter. These new roofs are of the welded gas-tight type, similar to the roofs on the new tankage.

Welded construction was adopted throughout and the specialized technique developed by these contractors was followed in co-operation with the consulting engineers.

The necessity of a special technique for the erection and welding of steel tanks was early realized by the Whessoe engineers, and the throughput of large numbers of welded steel tanks is evidence of the success of their methods.

The welding designs, details and schedules were submitted to the consulting engineers for approval on behalf of the company and the whole of the work was carried out under the scrutiny and check of the consultant's resident engineer and visiting staff.

It is the programme of Manchester Oil Refinery, Ltd., to produce approximtely 20,000 tons of solvent refined and dewaxed, highest class lubricating, transformer and white oils, and up to 35,000 tons of conventionally acid-treated lubricating oil. Products will further comprise kerosene, gas oil, various types of Diesel and fuel oils, axle oil, dark cylinder stock, and printing ink oil, up to 60,000 tons total, and 10,000 to 20,000 tons of bitumen suitable either for road building, for insulating purposes or for the manufacture of paint, rooffelts, etc.

As a by-product of the solvent plant there will be a production of 3,000 to 5,000 tons of paraffin wax of various types, and possibly also a small production of petroleum jelly, if required by market conditions.